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CORRELATION BETWEEN THE FLOW CONDITIONS AND THE OPERATION REGIME OF A CERTAIN WASTEWATER SYSTEM

BY

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Abstract. For a certain sewerage system the designed operation parameters of the pumping station serving the wastewater treatment plant couldn’t be achieved. The problems reported by the personnel have leaded the Technical University of Civil Engineering, Bucharest, research team to multiple possible causes. One of this is related to the flow conditions ensured by the sewerage, a very complex hydraulic system, conceived and built long before the pump-treatment ensemble.

The paper presents the mathematical modeling efforts made by the authors to answer to the questions regarding the water level influence on the malfunction of the pumping station. Based on the developed model which analyses the entire system as a whole, several conclusions were driven for improving the operation capacity of the pumping station.

Key words: hydraulic system; free surface flow; sewerage system.

1. Aims and Background

Developed together with the localities they serve, the sewerage systems are in a continuous expansion. Although their design is done in different periods

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their functionality should not be affected by the new components integrated in the system. Unfortunately there are situations when after the execution of the new designed objects the occurrence of operational problems is reported. This is the case of the sewerage system analysed by the Technical University of Civil Engineering, Bucharest (TUCEB), research team.

During the last forty decades the analysed sewerage system was in a permanent expansion. Beside the new collectors several other modernization works were developed. In the eighties the main collector was completely reshaped and the works at a wastewater treatment plant were started. Due to the political changes which took place at the end of these years many of the started modernization actions were stopped. In the last years the resumption of the work which aimed the wastewater treatment plant was restarted several times. Until now the first of the designed wastewater treatment lines was completed.

Since the commissioning of the first treatment line operation problems related to the functioning of the five pumps of the wastewater pumping station line 1 were reported. The designed parameters are not met, namely the 10 m^3/s flow rate can not be taken and additionally the pumps were damaged after a short period of time.

The owner of the pumping station together with the designer and the contractor of the works tried to solve these problems. Numerical studies and surveys regarding the phenomena that occur in the suction chamber of the pumping station have been completed. The resulted reports revealed rotor damages that could be caused by erosion or cavitation. Despite these efforts the implemented solutions based on these studies failed to correct the situation.

Under these circumstances the owner of the pumping station and the operator of the sewerage system requested TUCEB a new expertise on the operation of the pumping station which aimed the solutions for solving the reported problems.

Based on the discussions with the operation personnel, the provided documents, on sites studies and monitoring campaigns, the TUCEB team identified multiple problems with a complex character which are the cause of the poor operation of the pumping station.

One of the analysed problems was related to the conditions necessary to be accomplished for ensuring a water level in the suction chambers for avoiding the occurrence of air in the pumping system.

In order to analyse the free surface level modifications produced in the studied sewerage system as a result of the flow conditions changes, a numerical model was carried out. The schematic diagram of the hydraulic system is shown in Fig. 1.

The data on which the mathematical modeling of the hydraulic phenomena was performed were provided by the beneficiary. They consisted in

plans, cross sections and data monitored by the command and data acquisition system of the WWTP (wastewater pumping station).

For additional data and field studies the TUCEB team has developed some measurement campaigns.

The numerical study was achieved using a software specialized for the free surface flow based on the one dimensional model which solves the flow eqs. using the finite difference method.

To accomplish the study five hypotheses were considered. The first and second one refers to the present situation without, respectively with pumping, the third, fourth and fifth hypotheses are related to the proposed solution for ensuring the necessary water level at the suction chamber of the pumping station namely the heightening of the weir crest placed in junction 2.

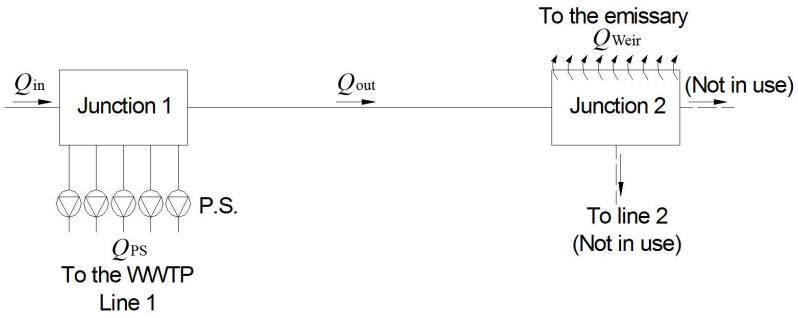


Fig. 1 – The analised hydraulic system – schematic diagram: Q_{in} – the flow rate upstream junction 1; Q_{out} – the flow rate downstream junction 1; Q_{Weir} – the flow rate discharged to the emissary; Q_{PS} – the flow rate pumped to the wastewater treatment plant; PS – pumping station.

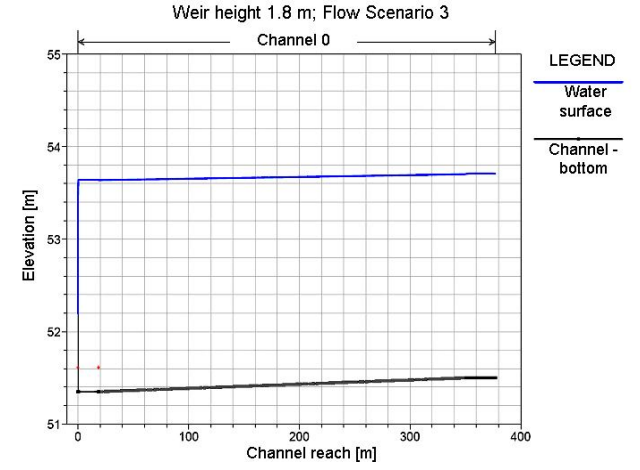
The first two hypotheses were used for calibrating the model. Afterwards the last three numerical simulations have provided data on the water surface elevations modification by increasing the weir crest with 13%, and no pumping, four pumps in operation and five pumps in operation.

2. Obtained Results

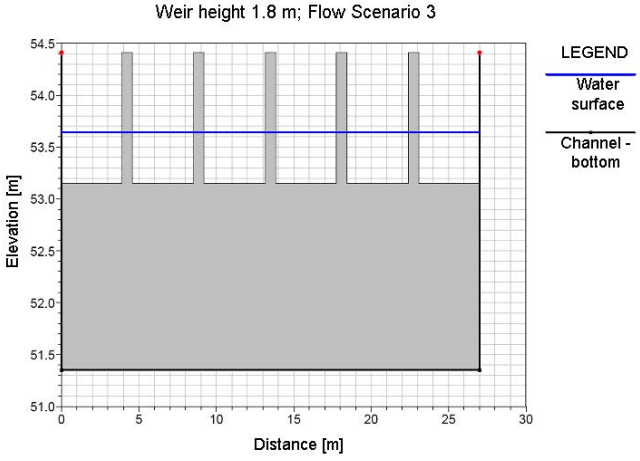
Because the first two hypotheses were used for model calibration only the last three will be presented and discussed.

In all the last three considered situations the weir crest elevation is increased with 0.23 m. Considering the head losses generated by the structural elements and the technological objects interacting with the flow (h_r = 0.05 m), the obtained results describing the flow conditions, and which are presenting interest for the study are related to the flow regime and the water level and water depth in some cross sections identified to be critical for the sewerage

system. The considered flow rate for all the analysed scenarios was 11.5 m^3/s, value suggested by the beneficiary of the study.



a

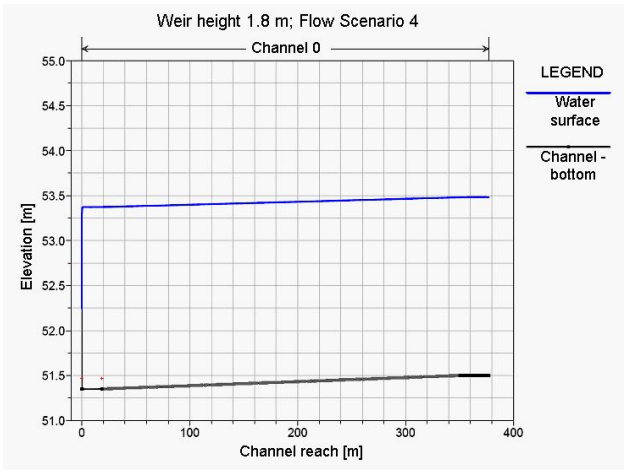


b

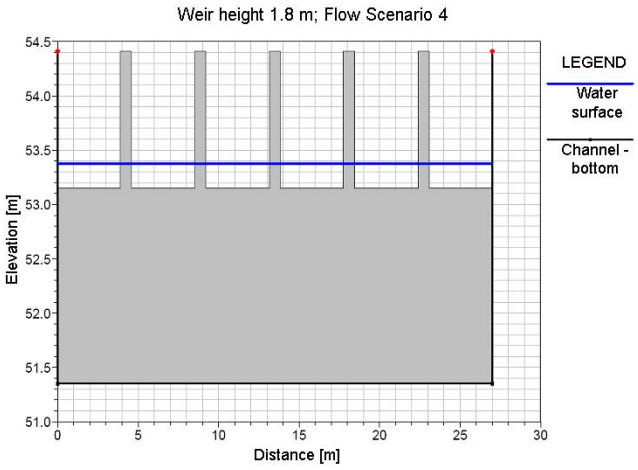
Fig. 2 – Graphical representation of the modeling results for the third scenario: *a* – free surface shape between junction 1 and junction 2; *b* – discharge section – front view of the weir.

The third scenario beside the weir crest elevation modification from 52.92 to 53.15 (0.23 m) assumes that the pumping station is turned off. Under the aforementioned circumstances the flow regime was classified as tranquil; the free surface shape is similar to that presented in Fig. 2 *a*; in the controlling section (the discharge section) the elevation value of the water surface is 53.64,

which leads to a water depth value of 2.29 m (Fig. 2 *a*); the head over the weir crest is 0.49 m (Fig. 2 *b*); the mean depth of the water in the studied channel reach is 2.25 m; the water depth in junction 1 is 2.21 m; the water depth in the suction chamber of the pumping station is 4.59 m.



a



b

Fig. 3 – Graphical representation of the modeling results for the fourth scenario: *a* – free surface shape between junction 1 and junction 2; *b* – discharge section – front view of the weir.

The fourth modeling scenario assumes the same geometrical conditions as for scenario 3, the difference is related to the operation of the pumping station in this case for pumps are in use. The flow rate of the pumps is 2 m^3/s each. The flow regime is tranquil. The shape of the free surface is shown in Fig. 3 *a*. The

value of the water surface elevation in the discharge section is 53.37; the obtained water depth value in the controlling section is 2.02 m; the head over the weir crest 0.22 m (Fig. 3 *b*); the mean depth of the water in the studied channel reach is 2 m; the water depth corresponding to junction 1 is 1.98 m; the water depth in the suction chamber of the pumping station is 4.31 m.

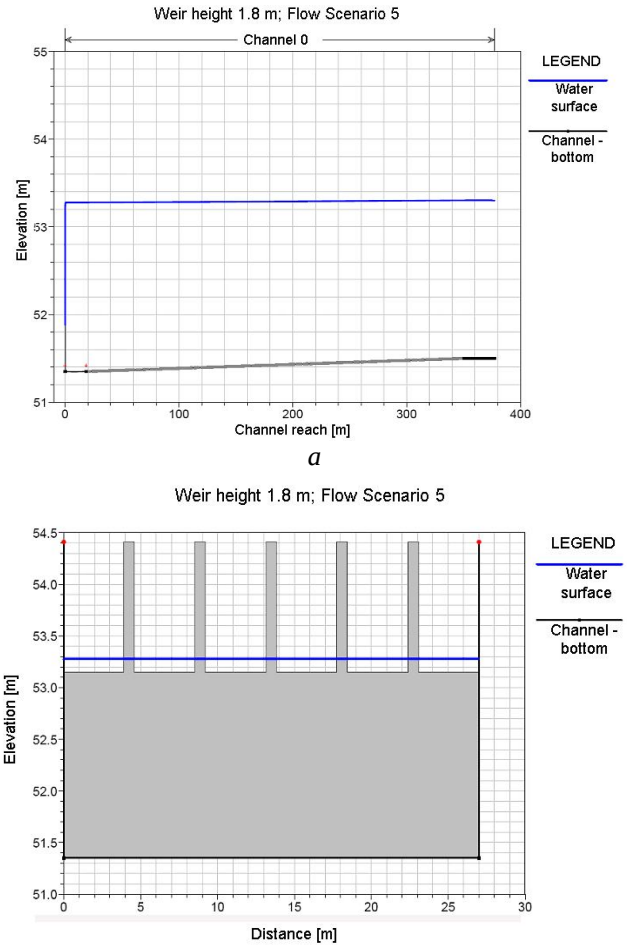


Fig. 4 – Graphical representation of the modeling results for the fifth scenario: *a* – free surface shape between junction 1 and junction 2; *b* – discharge section – front view of the weir.

For the last modeling scenario the same geometrical condition were considered. The pumping station was considered fully in use, namely all five pumps are turned on. Thus, from the total flow rate entering junction 1, 86.96 % is pumped to the WWTP and only 13.04 % is flowing to the emissary.

Under this circumstances the flow was also classified as tranquil, the water surface elevation over the weir crest is 53.28, the corresponding water depth is 1.93 m and the value of the head over the weir crest 0.13 m. The mean depth value of the water in the channel reach bounded by the two junctions is 1.8 m. For the water depth corresponding to the suction chamber the obtained value is 4.13 m. The results are shown in a suggestive manner in Fig. 4.

3. Conclusions

For solving the problems encountered in complex hydraulic systems the operators are mostly looking for local solutions neglecting the interaction of all the elements present in that system. As a result in most cases focusing strictly on the phenomena considered to be directly responsible for the malfunctioning doesn't lead to the detection of the real causes which are generating those problems.

Although the weir placed in junction 2 was designed as a lateral weir, in the current operation conditions it functions as a frontal weir which discharges the whole quantity of water coming out from junction 1.

The results obtained by mathematical modeling have reveled that for all scenarios the necessary water level for a safe operation of the wastewater pumping station are achieved. Unfortunately for validation of the modeling results with experimental observations the operator must first apply the recommended solution and afterwards to develope new on site measuring campains. Both of this are uncontrollable by the modelator.

For the fifth scenario, namely a 1.8 m weir height and five pumps in operation at maximum capacity, the obtained water surface elevation value is similar to the present situation when the weir height is 1.57 m and four pumps are turned on. For lower flow rates than the value used in the numerical study it is possible that the water level at the suction chamber of the pumping station to be below the safety level. This shows also that for a constant flow rate the correlation between the weir crest level and the pumping capacity used at a certain moment is very important.

For ensuring a greater water depth in the suction chamber of the pumping station and thus increasing the operation safety of the system, a solution for rising the discharge level at the weir placed in junction 2 is required.

A safe functioning of the pumping station placed in junction 1 imposes that all involved elements to be treated and operated as a hydraulic system not as entities. Thus, the correlation between the water levels in the discharge section and the depth in junction 1 must be considered. For achieving this aim a permanent water level monitoring in junction 1 and 2 is necessary. Also the correlation between the two water levels and a variable discharge elevation will lead to best results for the system operation.

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CORELAREA CONDIŢIILOR DE CURGERE ŞI REGIMUL DE EXPLOATERE AL UNUI ANUMIT SISTEM DE CANALIZARE

(Rezumat)

În cazul sistemului de canalizare studiat, parametrii de exploatare proiectaţi pentru funcţionarea staţiei de pompare ce deserveşte staţia de epurare a apelor uzate nu au fost îndepliniţi. Problemele semnalate de personalul staţiei au condus echipa de cercetare formată din specialişti din cadrul Universităţii Tehnice de Construcţii Bucureşti (UTCB) la suspectarea mai multor cauze posibile care generează funcţionarea necorespunzătoare. Una din acestea este legată de condiţiile de curgere existente în reţeaua de canalizare, un sistem hidraulic foarte complex, conceput şi executat cu mult înainte de ansamblul pompare–epurare.

Se prezintă rezultatele obţinute în urma modelării matemetice realizate de autori privind influenţa nivelurilor de apă asupra exploatării staţiei de pompare. Pornind de la realizarea modelului matematic ce priveşte sistemul de canalizare ca un întreg, echipa UTCB a tras o serie de concluzii pe baza cărora se poate îmbunătăţi funcţionarea staţiei de pompare a apelor uzate.