EVALUATION OF INFILTRATION FLOWS IN "COSTA DO ESTORIL" SUBSYSTEM CATCHMENTS

Filipe Guerreiro [(a)]

[a)] Estudante de Mestrado em Engenharia Civil, Instituto Superior Técnico, Universidade de Lisboa, filipe.guerreiro@tecnico.ulisboa.pt

ABSTRACT

Infiltration in urban drainage systems is unavoidable. It results in bad performance and degradation for the system and to higher costs to residents, which are caused by the increase in flow rates that lead to higher operational costs in waste treatment plants and transportation. These undue affluences tend to be aggravated by the system's degradation and aging. Because of these, it is important to evaluate the drainage systems, to better instruct intervention by their public utility. It is useful to evaluate the hydraulic behavior with mathematical simulation models during the stages of planning and operation of new or rehabilitated drainage systems. An example of such a model is Storm Water Management Model (SWMM). In this thesis, I evaluate the infiltration flow rates in the general interceptor of the Estoril Seaside Subsystem for the Summer dry season, using the SWMM. To that end, in this thesis I have calibrated and validated a model of the Estoril Seaside Subsystem for the general interceptor. Due to the characteristics of the general interceptor and a long network of residual flows that are lagged over time, we can test the reliability of conventional methods in estimating infiltration. Lastly, we use the model and evaluate the infiltration flows, also using the regulatory decree (Decreto Regulamentar nº 23/95) of August 23rd. The results will serve as support to the work of the managing public utilities and improve future work.

Keywords: Assessment of structural performance; Dynamic simulations models; Infiltration; Modelling; Undue inflows; Wastewater drainage systems

1 INTRODUCTION

With the increasing expansion of urban centers, it is increasingly important to ensure the proper functioning of wastewater drainage systems. Undue influxes are a problem that concerns a significant part of the management entities insofar as they contribute to the increased operating costs of drainage systems and Wastewater Treatment Plants (WWTP), reduce their effectiveness and jeopardize the sustainability of management of urban drainage systems (Kracht et al., 2008). This phenomenon is exacerbated by the occurrence of certain precipitation events that cause the rise of groundwater levels and promote the undue entry of rainwater into the sewage drainage network, which may lead to system overload.

The company Águas de Lisboa and Vale do Tejo (AdLVT) is particularly interested in the elaboration of a research project with the purpose of analyzing and quantifying undue influxes in the drainage subsystem of the Costa do Estoril, represented in Figure 1. This drainage subsystem is one of the largest inter-municipal systems in Portugal, and includes an intervention area of approximately 245 km^2, serving about 720 000 inhabitants. This drainage system consists of 20 gravitational emitters, which develop along water lines in the municipalities of Amadora, Cascais, Oeiras and Sintra, and by 9 elevation stations. This subsystem has been designed as being of the domestic separative type, however it is notable the occurrence of undue influxes, namely pluvial, which, in practice, gives it a pseudo-separative type behavior.

The previously mentioned research project consists of the creation of a dynamic simulation model of the drainage subsystem of the Costa do Estoril with the aid of Storm Water Management Model software. Subsequently, the calibration and validation, in dry weather, of the general interceptor of the Costa do Estoril subsystem will be performed, and the minimum flow rates in the general interceptor will be analyzed based on a lag of the daily flow pattern in order to determine if a flow attenuation occurs on the network. Finally, an assessment of the infiltration rate in the general interceptor will be made through regulatory decree (Decreto Regulamentar nº 23/95), of August 23rd.

Dynamic simulation models, when well calibrated, can be a good tool for the quantification of undue influxes, as well as for the detection of the origin of the problem and the elaboration of plans of action with a view to their mitigation.

FIGURE 1 - SCHEMATIC REPRESENTATION OF THE COSTA DO ESTORIL DRAIN SUBSYSTEM (EPAL)

2 Methodology adopted

The methodology adopted includes the creation of a dynamic simulation model of the drainage subsystem of the Costa do Estoril using the Storm Water Management Model software.The dry-time calibration of the general interceptor was performed in order to evaluate the inflows improper.

The minimum nocturnal flow rates in the general interceptor are evaluated, in the perspective of quantifying infiltration flows.

The calibration and validation of the model, in dry weather, was performed for the summer period, considering the standard hydrographs obtained by Rosmaninho (2017), as well as the flow monitoring data of 3 days of the summer period (05/08 / 2015, 08/09/2015 and 03/09/2015) selected at random. The following WaPUG (Wastewater Planning User Group, 2002) criteria were considered for model calibration: volumetric error within the range [-10%; 10%], tip flow error within the range [-10%; 10%], shape comparison of the simulated hydrograms with those collected at the various system flow meters. The purpose of the calibration and validation in dry time is to achieve, after an iterative process of simulations, the values of average flow, which is introduced at all points where there are flow inflows, which are best suited to the model.

In the general interceptor it is intended to analyze the nocturnal minimum flows, which are an essential parameter for the estimation of the infiltration rate in the drainage nets by conventional methods. To perform this analysis, the input data that define the contribution of the flow upstream of the network is introduced first. With the simulation of the model, the flow data for the collector upstream of the WWTP are extracted in the downstream section of the network. Taking into account these flow data as a function of time, a hydrograph is constructed that represents the flow behaviour inside the collector upstream of the WWTP, due only to the first contribution. Then, considering the flow data of the first contribution, the input data of the next contribution is introduced. After the second simulation, the drainage data simulated for the collector upstream of the WWTP is extracted again from the model and a new hydrograph is constructed that allows comparing with the first one and determining the instants of time in which the minimum flows are verified. Then the process is repeated until the final simulation that takes into account all the contributions of flow. The hydrographs obtained and the instants of time where the minimum flow rates occur, allow to verify the attenuation of the daily flow pattern. In order to confirm the flow attenuation, the sum of the simulated minimum flow rates of the emitters and the simulated flow rates for the collector upstream of the WWTP is compared. In order to do this, the final simulation is used and the data of simulated flows of the collectors are taken more downstream of each of the emissaries and of the collector upstream of the WWTP. Simulated flow data show the values of the minimum flows and the time instants in which they occur. The minimum flow values of the emitters are added and compares with the minimum flow obtained for the collector upstream of the WWTP.

3 Description of the simulation model

Initially, a review was made of the set of cadastral data available on the Costa do Estoril subsystem. The collection and organization of data is an essential step in the development of a good model of dynamic simulation of any drainage system.A technical visit to the field was carried out in order to improve the understanding of the whole system under analysis, both at the structural level and its operation.

The creation of the physical part of the simulation model was done using the SWMM commercial software, by means of the elaboration of an Excel file, containing the necessary information on all the chambers and the collectors (Conduits) and was later converted into a SWMM software file (file with inp extension). In this model, more than 3,500 manholes and more than 3,500 manholes were defined. In addition to these two physical elements, other elements are also part of this drainage subsystem, namely: hill stations, river basins, emergency unloaders, storage units, flow distributors, pumps, etc.

After this, 5 udometric stations were introduced in the model and 5 time series were created, each one inherent to the respective udometric station, with registered precipitation values for the year under review (01/11/14 - 10/31/15). Subsequently, the sub-basins were gradually created and delimited in the model, and more than 50 sub-basins were defined. In addition, 9 lift stations were created in the model through storage wells and 29 pumps, with the respective control rules, distributed by the various stations. In relation to the subsystem's exit channels, 11 channels were introduced, located in the General Interceptor, in the Lage basin and in the WWTP. With the exception of the existing submarine emissary in the WWTP, the remaining exit channels introduced in the model represent emergency discharges.

Figure 2 shows the final result obtained for the Costa do Estoril simulation model.

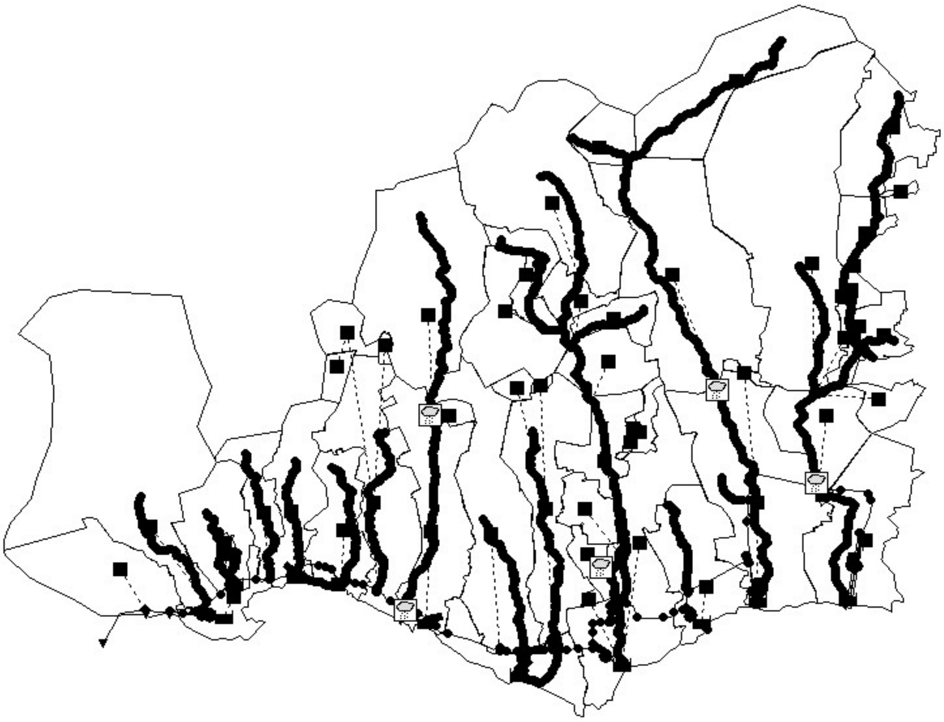

FIGURE 2 - SCHEMATIC REPRESENTATION OF THE FINAL RESULT IN THE PHYSICAL MODEL OF THE COSTA DO ESTORIL DRAIN SUBSYSTEM

4 Evaluation of infiltration flow in the general intercetor

Using a simulation of the mathematical model of the Costa do Estoril Subsystem, a procedure was performed to analyze the lag of the daily flow pattern for the flow meter Q10 (Figure 3), downstream of the general interceptor.

FIGURE 3- LOCATION OF THE ALFUENCES IN THE SYSTEM OF COSTA DO ESTORIL

The procedure adopted was initially to simulate the behavior of the interceptor at the point relative to the flow meter Q10, considering only the inflow of flow (described by the unit standard hydrograph and mean flow rate) of the Jamor emissary (measured by the Q02 meter) at the upstream end of the system. The simulation of the model was only carried out with this contribution and through the simulation the representation of the simulated hydrograph was obtained for the collector downstream of the flow meter Q10. Subsequently, new simulations were performed adding to the model each of the emitters affluent to the interceptor, from upstream to downstream. Therefore, the 12th simulation (Q46) accounted for the contribution of the emissary of the Mochos (flow meter Q46) and all previous emissaries defined in Figure 3, with a red circle. The contributions of the emitters of Porto Salvo, Cadaveira and Vinhas were not considered because they came to lift stations which, given the start and stop cycles of the electric pump groups, do not allow the occurrence of minimum overnight flows. The final simulation accounted for all inflows to the general interceptor including the lift stations. Figure 4 shows the hydrographs along the simulation process described, for the dry time (on 08/8/2015), a time lag is observed, relative to the minimum hydrograph values.

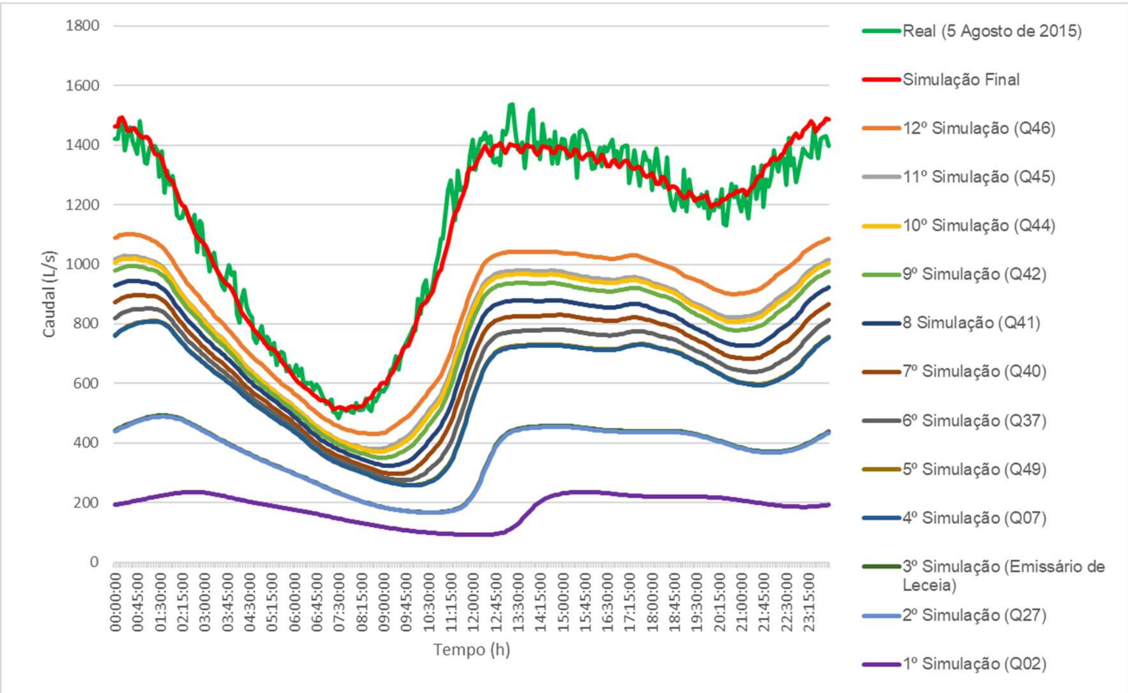

FIGURE 4 - HYDROGRAMS OF ALL SIMULATIONS AND HYDROGRAM 5 AUGUST 2015

Based on the hydrograms previously shown, Table 1 was defined, referring to the minimum flows and time instant observed for each of the previous hydrograms. Based on Figure 4 and Table 1, a time lag is observed, relative to the minimum hydrograph values, of 4h and 25 min.

TABLE 1 - MINIMUM FLOWS AND MOMENT OF TIME THESE FLOWS DOWNSTREAM OF THE OUTFALLS THROUGH MODEL

Q10 Hydrograms	Minimum flow (L/s)	Minimum flow time (h:m:s)
1º Simulação (Q02)	92.2	12:10:00
2º Simuação (Q27)	165.9	10:40:00
3º Simulação (Emissário de Leceia)	167.1	10:35:00
4º Simulação (Q07)	257.7	10:00:00
5º Simulação (Q49)	259.4	10:00:00
6º Simulação (Q37)	275.3	09:40:00
7º Simulação (Q40)	296.6	09:25:00
8º Simulação (Q41)	323.8	09:10:00
9º Simulação (Q42)	349.4	08:55:00
10º Simulação (Q44)	370.4	08:55:00
11º Simulação (Q45)	379.3	08:50:00
12º Simulação (Q46)	430.9	08:40:00
Simulação Final	510.3	07:45:00
Real (5 Agosto de 2015)	484.2	07:30:00

was necessary to compare the sum of the simulated minimum flow rates of the emitters with the minimum simulated flow rate to the collector downstream of the flow meter Q10, taking into account only the flows in the network of the same emitters. As before, also at this stage for the same reasons, the lift stations and the emissaries of Porto Salvo, Cadaveira and Vinhas were not considered.

From the data analysis of the 12th simulation (previously defined in the previous process and taking into account the inflows of all the emitters in the general interceptor), it was found that, in the downstream section meters of the different emitters, the minimum flows would occur, as is between 0h and 6 am (Cardoso et al., 2002). However, for data collected on the Q10 meter (referring to the "12th Simulation" of the model which takes into account the contribution of the emissaries, identified in Table 2), located in the section at the downstream end of the general interceptor, immediately upstream of the WWTP, the minimum flows would occur around 8:30 am about 4 hours after each emissary.

TABLE 2 - MINIMUM FLOWS AND MOMENT OF TIME THESE FLOWS DOWNSTREAM OF THE OUTFALLS THROUGH

Emissary	Minimum flow (L/s)	Minimum flow time (h:m:s)
Mocho	53.2	05:05:00
Castelhana	1.8	04:10:00
Amoreira	5.6	04:05:00
Bicesse	18.0	04:05:00
Caparide	20.5	06:10:00
Marianas	15.6	06:55:00
Sassoeiros	11.1	04:05:00
Laje	89.8	06:15:00
Leceia	1.1	04:05:00
Barcarena	62.1	06:25:00
Jamor	91.5	05:05:00
Total	375.9	

It was verified that the contribution of the inflows to the minimum flow in the section downstream of the Q10 flow meter was 430.9 L / s, which occurred at 8:00 am and 40 min in the morning and that the sum of the simulated minimum flows from the inflows of the different emissaries was 375.9 L / s. The moments of time of the minimum flows of the emissaries are comprised between 4h and 5min and 6h and 25min in the morning.

Based on these data it is concluded that there is an attenuation in the general interceptor of the minimum flow rate of more than 4 hours. The different inflows of flows in the general interceptor, offset in space and time, cause the daily flow pattern to be attenuated, influencing the flow rate and the instant of time in which the minimum and maximum flow occurs for the monitoring point before the Wastewater Treatment (WWTP), Q10. This effect leads to great uncertainties in the quantification of the infiltration base flow through conventional methods, which are based on the hypothesis of minimum night flows and are based on the measurement of the minimum flow through the analysis of dry time flow records. Invalidating the estimation of the flows of infiltration in that infrastructure through the method of minimum night flows.

In order to estimate the infiltration flows and verify their compliance with the indicative value mentioned in Regulatory Decree No. 23/95, of August 23 (which relates the infiltration flow rate to the diameter and length of the collectors of the network) the section corresponding to monitoring point Q10 were determined, as well as the average daily flow volumes for each monitoring point. The difference between these volumes, in the sum of the minimum flows of each emitter, allowed to estimate, in a very satisfactory way, the average daily volume of undue inflows to the inter-buster. The obtained volume was 8342 m^3, representing 8% of the total volume in section Q10. Assuming that this volume is due solely to infiltration, based on cadastral data, diameters and lengths of collectors of the general interceptor, the indicator of the regulatory decree on the order of 1,86 m^3/dia/(cm.km), between the values of 0.5 and 4 m^3/dia/(cm.km), mentioned in the Regulatory Decree.

5 Conclusions

The main objective of this project was the construction of a mathematical model of the drainage subsystem of the Estoril Coast, together with its calibration and validation, regarding the general interceptor in dry weather.The model was then used for evaluating the respective minimum flows and the quantification of infiltration.

The general interceptor is an extensive network with multiple inflows lagged in space and time. Its peculiar configuration causes an attenuation of the pattern of the daily flows and consequently a minimum flow rate in the collector upstream of the WWTP higher than the sum of the minimum flows of its contributions. Due to this difference and the moment of time that the minimum flow in the collector upstream of the WWTP is verified, at 8h and 40min, it is concluded that the conventional method of minimum night flows, which is currently used to estimate infiltration rates, is unreliable. Due to the lag of minimum flows, the method of minimum night flows for the estimation of undue inflows, in dry weather, in the general interceptor is not applicable. At the outset, in large drainage systems with a similar configuration will also not apply.

Regarding the evaluation of the infiltration rate in the general interceptor based on the regulatory decree nº 23/95 of August 23, 1995,the value of 1.86 m^3/dia/(cm.km) falls inside the recommended range and as such, the conservation status of this network is acceptable.

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