PERFORMANCE CHARACTERIZATION AND EVALUATION OF FLOW CONTROL TECHNOLOGIES– APPLICATION TO STUDY CASES

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Abstract

In the unitary drainage systems, and in the majority of the separative systems, it is verified the affluence of pluvial or groundwater flow, often designated by undue inflows, which entail high treatment costs and, sometimes, result in a deficient hydraulic and environmental performance by the system. In these situations, is usual to resort to the flow regulation for a preset value of flow, limiting the affluence to the "high" system and discharging the excess flow, frequently above from 2 to 3 times the peak flow in dry weather, to the watercourses.

The regulation for a pre-defined flow, from the several collectors which transport domestic wastewater to the WWTP, has been progressively improved through the evolution of mechanical equipment, the flow control valves.

The flow regulation is required, essentially, due to the strong pluvial contribution which circulates at the same time with the domestic wastewater, that doesn't need an extensive treatment at the WWTP, being able to be directly discharged into a near watercourse, before inflows to the treatment plants. Even in collectors considered as separative, due to the undue inflows problematic, this process of flow regulation has been increasingly a recurring solution.

In a simplified way, the flow regulation valves are mostly mechanical and of two types (the float type and the vortex type), although, began to appear electric and electronical models in the market. Their operating process is distinct, but both have, as final objective, the maintenance of a downstream flow always inferior or equal to the valve design flow, and that will depend on the upstream water level.

During the design phase still exists some incertitude about which one is the best equipment solution to use in which case, albeit, to be possible to choose better solutions in future projects, is firstly necessary to deepen the knowledge about the already installed models' operation. In this sense, were approached two study cases, in this dissertation, getting some conclusions about the behaviour of two flow regulation valves, identifying problems, and suggesting ways of improvement that could be useful in future constructions.

Keywords: sanitation, urban drainage, flow regulation valves, flow regulation, monitoring.

1. Introduction

The present study aims to a performance evaluation of solutions used in two sanitary works, realized in Lisbon, in order to define valid and substantiated arguments that allow to decide about which one is the best flow regulator valve type to apply, in each intervention case.

What has been verified is that, because of the limited information and relative lack of experience about the flow regulators, the designers' option is mostly to opt for solutions already used in previous projects, similar to the ones in developing, which has stagnated the option for new models potentially more advantageous.

The performance evaluation of two different equipment, in two distinct works, performed by the same constructor enterprise, is possible thanks to flow measuring systems and precipitation data from udometers.

It is firstly intended to obtain a clarification about the main offers in market, expanding horizons in the design future phases, in a way which to expose their operation processes and dimensioning criteria in order to adequate each solution, to the conditioning, of each future project. It will allow the optimization of the flow regulators and, at the same time, ensure that the WWTP affluent flow be such that will potentiate it optimal operation.

2. Flow regulation valves

The inflow control, of unitary flows, was usually done using the conventional dischargers, dimensioning it to have the crest at the same level of the uniform regime high, correspondent to the flow pretended to discharge (Matos and Sousa, 1987; Sousa and Matos, 1991).

However, this type of equipment doesn't have a perfect operation and is currently in disuse. Is now considered more adequate the flow control valves implementation, which allow an effective control of the interceptor systems inflows.

In case of flow control valves use, it will be planned the utilization of a storage reservation to minimize the discharge effects in the environment. This flow reservation shall be able to store a water volume equals to the "first flush" because those are the highest expected pollutant loads.

In its simplest form, the reservoirs, where the flow regulator valves are installed, are divided in four chambers (Matos and Sousa, 1987; Sousa and Matos, 1991):

- A **central chamber**, which has a gutter through which wastewater flows, from the unitary collector until the flow regulator valve, and which is separated from the retention and discharge chambers.
- A **retention chamber**, which is intended to the inflow flow storage when is exceeded the capacity of the first chamber.
- A **discharge chamber**, to where is transported the flow excess that the previous chambers couldn't store, being the effluent forwarded to a near watercourse.
- A **dry chamber**, where is installed the flow regulator valve.

Yet, is important to distinguish between valve installations in wet chamber or dry/semi-dry chamber. In the wet installation, the flow regulator is in the central chamber, being underwater when the storage flow increases; and, in the dry/semi-dry installation, the valve is located in an adjacent chamber, the dry chamber.

It is understood that, at the equipment maintenance level, the dry installation facilitates the processes of visiting, cleaning and repair of the valves, however, the option by a wet installation is the most frequent because encompasses lower construction costs and demands less dimensioning precautions.

In short, the flow regulation valves are an appropriate form to do a unitary flows more efficient control during the rainy weather, being designed to allow the transport from one to three times the peak flow in dry weather, and discharging the flow excess, sufficiently diluted, into a watercourse (Matos and Sousa, 1987; Sousa and Matos, 1991).

The type of models in market is very miscellaneous, highlighting two types of regulators, the vortex valves and the float valves.

Through a study of the available flow regulators, was possible to understand that the market is dominated by a restricted group of enterprises, which are the ones enabled to fabricate the equipment but also the only ones that can repair the flow control valves after being installed. Currently, exists a great variety of models depending on the design control flow and on the upstream water level, to which the valve will be subjected, highlighting the following ones:

Table 1 –Available flow regulator valves

Float Type			**Vórtex Type**		
Equipment	**Design Flow**	**Upstream level**	**Equipment**	**Design Flow**	**Upstream level**
	(L/s)	(m or DR)		(L/s)	(m or DR)
HydroSlide MINI	1 to 5.390	Up to 3,5 DR	**Cyclone CYE**	10 to 600	Up to 6,0 m
HydroSlide VM	61 to 770	Up to 3,5 DR	**Cyclone CYO**	10 to 600	Up to 6,0 m
HydroSlide VN	5,1 to 1960	Up to 7 DR	**Cyclone CYEO**	10 to 600	Up to 6,0 m
HydroSlide VS	1 to 770	Up to 13,5 DR	**Cyclone CYDK**	8 to 80	Up to 6,0 m
HydroSlide GM	5 to 60	Up to 13,5 DR	**Cyclone CYDV**	20 to 500	Up to 6,0 m
HydroSlide Combi	8 to 60	Up to 4,0 m	**Cyclone CYDX**	25 to 600	Up to 6,0 m
HydroSlide FlatFlow	8 to 60	Up to 2,50 m	**Cyclone CEV**	0,2 to 80	variable
ALPHEUS	2 to 2400	variable	**Cyclone CEH**	4 to 30	variable

Depending on the valve type chosen in project, the installation chamber design, as well as the other chambers, will be different and with distinguish conditionings. Hereupon, more than general recommendations are possible to identify minimum dimensions which shall be adopted to each project.

As initial consideration, is important to know that, for a float type installation in dry chamber, is mandatory to proceed to a correct output collector design, ensuring that all the discharged flow is routed downstream without the possibility of flood the chamber. Furthermore, the discharged flow is directly related with the distance between the valve threshold and the collector, wherein is recommended to consider a minimum distance of 60 to 70 mm for flows inferior to 180 L/s, and 80 to 90 mm to flows superiors to 440 L/s (Matias, *et al*).

Additionally, must be thought a vertical distance between the central chamber entrance and the valve of 250 mm, and the bypass exit must be higher than the flow regulator superior part (Matias, *et al*).

Taking into account the plant dimensions, the float type valve is bigger than the vortex solutions, and as minimum area of the installation chamber, shall be respected 2x2 m^2, however it will depend on the chosen model, access conditions and other project conditioning (Matias, *et al*).

In agreement, for the vortex models, is also imperative a correct output collector design for the same reason explained before. Therefore, the wastewater may be transported by a concrete or PVC structure, and the recommended distance between the valve threshold and the collector is 100 to 160 mm for flows inferiors to 60 L/s, and up to 400 mm for flows until 800 L/s (Matias, *et al*).

It is also fundamental to ensure a level difference between the central chamber and the valve of 0,15 to 0,30 m, and the bypass must be higher than the flow regulator.

Concerning the central chamber minimum dimensions, once again it will strongly depend on the model and on the project conditioning, but shall never be smaller than 1,5x1,5 m^2 in plant (Matias, *et al*).

3. Study cases

3.1 Installed solutions

The two addressed study cases were based in the analysis of two different flow control solutions (one vortex and one float type), for two distinguish urban basins, which make it flow to the collector dissimilar amounts of wastewater in direction to the WWTP.

They are the basin of Alfornelos (Frielas system) and basin of Caselas (Alcântara system), which revealed a significant problematic due to the notorious pluvial contribution, that circulates along the domestic collectors, and which inflow to the WWTP without the necessity of an extensive treatment, being able to be directly discharged to a near watercourse, increasing the pollutant concentration which arrives to the WWTP, and optimizing the treatment process as the associated costs.

The chosen solutions were included in the pluvial flow control plans and are indicated below.

Table 2 – Adopted flow regulator solutions in both study cases

Project	Peak flow in dry weather	Design flow	Flow regulator valve	Type
	(L/s)	(L/s)		
Alfornelos	61	120	HydroSlide MINI	Float
Caselas	10	20	Cyclone CYDX	Vortex

3.2 Data analysis

The elaborated analysis was based on a data sample of flow velocity and water level, after an adequate information validation process. That sample allow the identification of hourly, weekly and monthly behaviours of wastewater affluence to the study systems, and also the pluvial flow influence perception, in the total behaviour, when were identified precipitation periods.

Concerning to the case of Alfornelos, the June of 2016 was identified as a predominantly dry month, with only 3 peaks of flow, which corresponds to precipitation days but without a significant intensity or duration. From a general point of view, in the dry weather, with the implementation of a float control solution, the domestic wastewater is totality arriving to the WWTP, as intended to be.

In contrast to the dry weather behaviour, during the month of November of 2016 took place various precipitation events, with significate duration and intensity, being registered, by the flow measuring system of name "*ADS Flowhawk*", peak flows of 130 to 140 L/s.

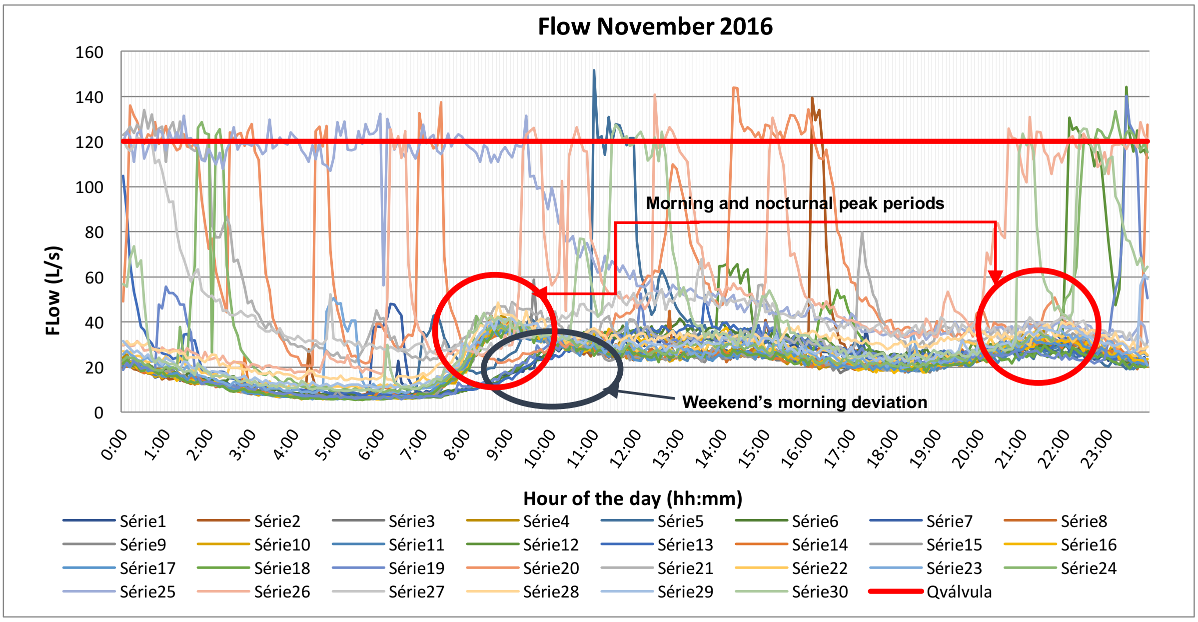

Image 1 - Registered downstream valve flow data at November 2016 in Alfornelos (after valve installation)

At a distance of thereabout 9 kilometres, is located the basin of Caselas, where the study was exactly the same than done for Alfonelos. The biggest difference between the two cases is the amount of flow which circulates inside the collector, wherein the maximum registered flow in Caselas was in the order of 14% of the maximum registered flow in Alfornelos. Therefore, the chosen flow regulator was obviously from other type, in this case a vortex valve Cyclone CYDX.

Considering, as before, the June of 2016 as a predominantly dry month, the analysis showed that all the domestic wastewater is totality arriving to the WWTP, as intended to be, not having registered any problem related to pluvial contributions.

On the other hand, the May of 2016 was a month of heavy rainfall, getting peak flow registers, by the Flo-Dar measuring equipment, of 25 to 27 L/s.

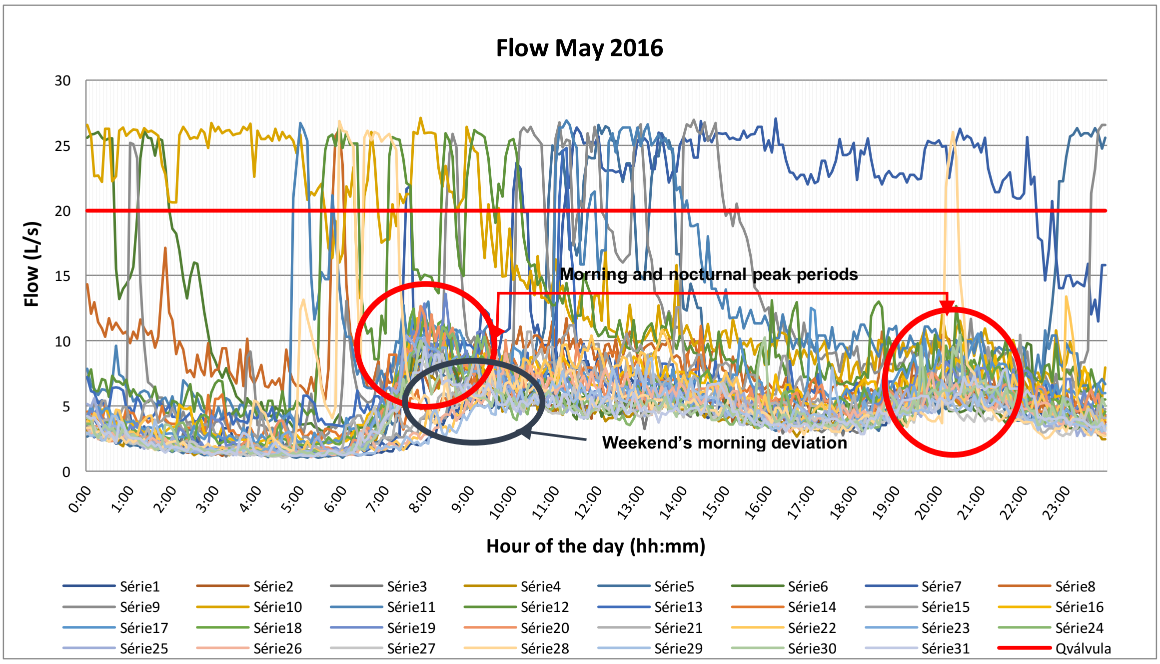

Image 2 - Registered downstream valve flow data at May 2016 in Caselas (after valve installation)

3.3 Results about the flow regulator valves behaviour

Study case of Alfornelos

After the analysis, was concluded, that was exceeded the valve design flow in 12,0% of the studied days, which corresponds to 21 days of registered flow superior to 120 L/s. Using all the 5-minute interval data, the design flow only was overpassed in 0,79% of the registers. Therefore, admitting a measurement error of maximum 9%, the flow default daily period it's between 0H12m and 2H43, which could represent a very good, or even perfect behaviour, attending the sediment deposition that always take place and which influences the operation.

Admitting, that the provided characteristic curve, describes perfectly the valve operation, and not being possible to obtain data about the upstream water level, one hypothesis was to calculate the maximum water level, expected to occur, in the case of Alfornelos.

Using the rational formula, with a return period of 2 years, and a dimensionless coefficient of 0,4, the peak flow for the basin shall be 7700 L/s. On the other hand, using the elaborated project, and knowing that the unitary collector, which inflows to the valve, has a diameter of 400 mm, a length of 1630 m and a 1,7% slope, the full section flow shall be 265 L/s (only 3,4%).

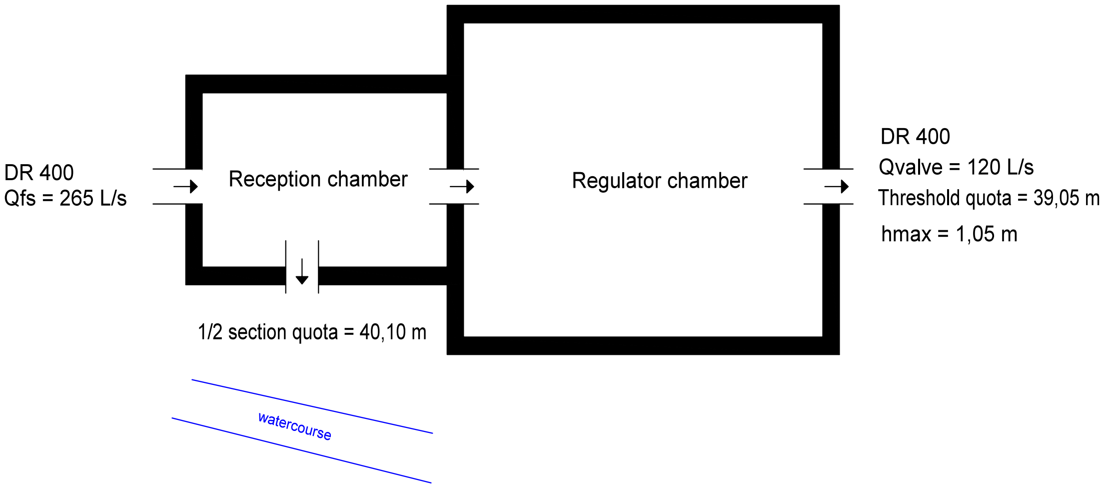

Image 3 - Scheme of the construction of Alfornelos

The direct discharge to the watercourse begins for a level of 1,05 m, according to the previous sketch of the chambers, because the valve is installed at a level of 39,05 m, and the direct discharge at a level of 40,10 m, so, the maximum upstream water level expected is 1,05 m. Interpreting the fabricant's characteristic curve, the level of 1,05 m corresponds exactly to a downstream flow of 120 L/s (the controller design flow), concluding about a very good behaviour of this solution in particular, and a well-planned and dimensioned chamber.

Study case of Caselas

Using a very similar analysis, was calculated that in 20,83% of the studied days, the design valve flow was overcome. This period corresponds to 20 days with a peak flow higher than the design flow, and using all the registers with measuring intervals of 5 minutes, the design flow was not respected in 2,57%

of the time, which corresponds to a default daily period it's between 2H47 and 3H05, that isn't so good than in the previous case, but can represent a satisfactory operational result.

Once again, admitting the characteristic curve as a perfect description of the valve behaviour, comes up the calculation hypothesis of the maximum water level, using the given project.

Knowing that the unitary collector, which inflows to the valve, has a diameter of 400 mm, and a 5,5% slope, the full section flow shall be 476 L/s. In the reception chamber exists a concrete structure, which proceeds to the direct flow discharge into the discharge chamber, when the water level exceeds 0,60 m. By the time this water level is reached, the discharge is done by a short tube which operates as an orifice.

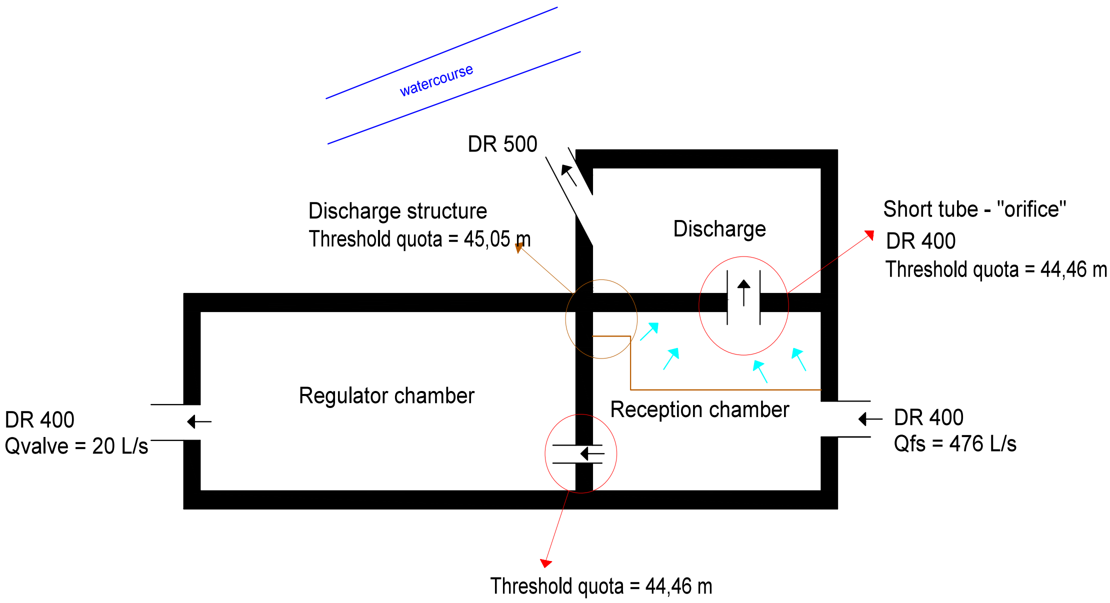

Image 4 – Scheme of the construction of Caselas

Using the expression given by Quintela (2014) for discharge by orifices:

$$Q = C\,A\,\sqrt{2\,g\,H} \qquad (1)$$

and, establishing as maximum discharged flow 456 L/s, because the valve design flow is 20 L/s, and the full section inflow is 476 L/s, the maximum height above the orifice axis is 1,80 m. In addition, the used C factor was 0,60, as suggested by Quintela (2014).

Accordingly, the maximum water level upstream the valve, will be exactly 1,80 m, and consulting the given characteristic curve, for the 1,80 m water level, corresponds a flow of 34 L/s, being that the maximum flow expected to pass, through the flow regulator, in direction to the WWTP.

This flow value is superior than the 20 L/s design flow, indicating a possible less appropriated behaviour. Once again, using the May 2016 data, and considering only the days when were registered a significate precipitation, the average peak flow was 25,18 L/s. Even whereas that the measuring equipment has an error of maximum 5%, this average peak flow will be out of the design flow interval, which indicates a worse behaviour than in the case of Alfornelos, but remains satisfactory.

4. Conclusions and future recommendations

In the unitary drainage systems, and in the majority of the separative systems, it is verified the affluence of pluvial or groundwater flow, often designated by undue inflows, which entail high treatment costs and, sometimes, result in a deficient hydraulic and environmental performance by the system. In these situations, is usual to resort to the flow regulation for a preset value of flow, limiting the affluence to the “high” system and discharging the excess flow, frequently above from 2 to 3 times the peak flow in dry weather, to the watercourses.

The regulation for a pre-defined flow, from the several collectors which transport domestic wastewater to the WWTP, has been progressively improved through the evolution of mechanical equipment, the flow control valves.

In a simplified way, the flow regulation valves are mostly mechanical and of two types (the float type and the vortex type), although, began to appear electric and electronical models in the market. Their operating process is distinct, but both have, as final objective, the maintenance of a downstream flow inferior or equal to the valve design flow, and that will depend on the upstream water level.

During the design phase still existing some incertitude about which one is the best equipment solution to use in which case, albeit, to be possible to choose better solutions in future projects, is firstly necessary to deepen the knowledge about the already installed models’ operation.

The purpose of this study was to evaluate the effectiveness of the solutions adopted in two sanitary works, carried out in the Lisbon district, in order to define valid and reasoned arguments, which will allow to decide on the best type of valve, to be applied to each intervention case.

What has been verified is that, due to the recent implementation of this type of technology, is currently notorious some inexperience, during the design phase, to choose the best solution to apply to each case. The trend has been the utilization of a same equipment type, already used in previous projects, reason that explains the stagnation around always the same models.

Thus, in a primary phase, the main market offers were clarified in order to expose the operating processes and basic design criteria of the regulators, adapting each solution to the constraints of each project.

Was also accompanied, the exploration teams in order to understand the main operational difficulties, in particular in cases of vortex models and in wet chambers.

The main evidenced problematic in the visited works, was related with the sediments accumulation, sometimes with big proportions, in front of section of the flow regulators. It was also reported, by the exploration entities, and is evident, that even existing a regular maintenance of the chambers, the frequency of it is not enough to avoid the affectation of sediments to the flow control process. During the period of time when the sediments are arriving to the chamber, its deposition modify the opening and closing valve procedure.

For this reason, a possible conclusion after the entire study, was to recommend that the execution project may include a retention chamber that allows the accumulation of sediments, of all dimensions, over a period of time that should be in agreement with the regular maintenance and cleaning visits, so that there is no disruption on the valves operation because, in addition to not achieving the intended operation, it will also result in faster wear of the valves, involving costs.

Particularizing the two study cases, was concluded that, both have a very adequate operational behaviour.

Despite of wasn’t possible to obtain measurements of the upstream level in rainy weather, during the development period of this dissertation, it was possible to raise well-founded hypotheses about the operation of the regulators, based on a range of flow values that is admitted to inflow to the valves in rainy weather, and on the measured flow downstream the valves. These hypotheses lead to conclusions about their operation, highlighting a perfect operationally in the case of Alfornelos and a quite satisfactory behaviour in the case of Caselas.

In addition, for Caselas’ work, despite the very satisfactory presented behaviour, this could be improved if, during the design phase, it had clearly indicated which model of equipment was intended to use, which didn’t take place, leading to the installation of a vortex model, which works, essentially, for higher flows than intended.

It is suggested that, in the near future, different study cases should be analysed with data of flow upstream the valves in rainy weather, if possible, during and after, pluvial events of high intensity and/or duration. In addition, this study should be extended to other works already done, covering all types of equipment models that already operate in Portugal, obtaining a more general knowledge about all models and in different situations, in order to try to find a pattern of behaviour which allows, more securely, to associate each type of solution with a set of constraints, that could be useful in future projects.

In conclusion, it is considered important, to the selection of the most appropriate solutions to each intervention case, that shall always exist representative data about the upstream water level of the valves, as precipitation data at the installation site.

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