LISBON TECHNICAL UNIVERSITY
SUPERIOR TECHNICAL INSTITUTE

WASTEWATER DRAINAGE NETWORK PROJECT OF PARADUÇA VILLAGE

EXTEND ABSTRACT

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DESCRIPTION OF THE SOLUTION

This project involves the study and design of an urban drainage system (UDS) in the village of Paraduça in the parish of Calde, in Viseu. The drainage network of this village will be performed by separate networks that will forward the domestic wastewater to the wastewater treatment plant (WWTP) of Vilar do Monte, and in this project will only include the wastewater network and its collectors, not being included the drainage of rainwater.

The design of this network was initially measured based on 1:25000 scale military topography. Later, an acknowledgment of agglomeration was made in order to update and validate the available information, including measurement of population to be served, the topographical limitations (the plant topography has a key role in the network design, since the drainage should be performed by gravity), the land might be available for deployment of infrastructure and the final destination of the local effluent (WWTP Vilar do Monte).

After a careful analysis of the site topography, it turned out to be impossible to drain the entire network to the WWTP of Vilar do Monte by gravity, the construction of at least one pumping station (PS) was necessary. The solution was to place the PS in the south of the village, in a spot with easy access, and the entire network unable to dispose the wastewater by gravity to the WWTP will drain then to PS, which in turn will direct the wastewater to an intermediate point on the network and then be drained by gravity to the WWTP.

BASE ELEMENTS

Population study

The censuses were requested from the National Statistic Institute, in order to obtain the necessary information of the population of Paraduça, thus obtaining viable values for the demographic situation of the village *(Table 1).*

Table 1 – Census data available.

	Resident Population [pop.]			**Buildings (housing) [-]**		
	Viseu	**Calde**	**Paraduça**	**Viseu**	**Calde**	**Paraduça**
1981	83261	2201	346	26920	731	113
1991	83601	1687	257	33467	765	117
2001	93501	1647	258	44506	1082	173

The annual development geometric rate of population and the future population for the year corresponding to the project horizon (2011, 2031 and 2051) were calculated. The results are presented below in *Table 2* and *3*.

Table 2 – Annul development geometric rate.

	t_a-t_0	P_a	P_0	k_g
1981-2001	20	258	346	**-0,0146**

Table 3 – Project horizon population.

	Project horizon		
	Year 0 2011	**Year 20 2031**	**Year 40 2051**
population [pop.]	223	166	124

Since there was no data on the floating population, an expeditious calculation was made. Through the census demographic data the average population per property in the region of Calde was calculated, then multiplied by the number of accommodation in Paraduça, thus obtaining the total number of inhabitants in it. The floating population *(Table 4)* is obtained by subtracting the number of residents from the total population previously calculated.

Table 4 – Floating population.

	Population per property	**Total pop. [pop.]**	**Float. Pop. [pop.]**
	Calde	**Paraduça**	**Paraduça**
2001	***1,522***	263	5

However, for the purpose of this project, it was decided to adopt more conservative values, using the population data of 2001 (to admit the possibility of maintenance for the population observed in the last census). In *Table 5* the project population is presented.

Table 5 – Project population.

	Paraduça Population		
	Resident [hab.]	**Float. [hab.]**	**Total [hab.]**
2011	258	5	263
2031	258	5	263
2051	258	5	263

Flow determination

For the distribution of the consumed flow by the network, the following must be considered:

- Domestic consumption;

- Commercial consumption*;*
- Industrial consumption*.*

Both the commercial and industrial consumption were not considered relevant to the network design due to the absence of any kind of industries or commercial services in the area of the network service.

Calculation of the population distribution over the network was made using the fictitious lengths method, and the flow attribution to the several water collectors was obtained from the water consumption in the distribution network, taking into consideration that only a portion of these, flow in the drainage network. According to Article n.º123 of the Decreto Regulamentar n.º23/95 (DR 23/95) the turnout factor should be used to calculate the flow that goes to the drainage network through water consumption, and the value of this factor is between 0,7 and 0,9 (in this project the f_a value it’s going to be 0,8).

The DR 23/95 states in Article 13.º, minimum values for the capitation according to the number of habitants. In this project it was taken into account domestic consumption, and this has to respect the minimum values mentioned above, and these are described in *Table 6*.

Table 6 – Adopted Capitations.

Capitations		
Capitation year 0 (resident population)	L/(hab.day)	120
Capitation year 20 (resident population)	L/(hab.day)	140
Capitation year 40 (resident population)	L/(hab.day)	150
Capitation (float population)	L/(hab.day)	150

For the drainage network design of the community Wastewater (WW) is used the peak flow in the horizon critical year of the project. This network was designed to the instantaneous peak flow rate in 40 years. The peak flow is obtained by increasing the domestic average consumption by a flash point factor and adding industrial and commercial consumption and infiltration flow. The peak factor can be estimated as described in Article 125.º of the DR 23/95.

According to the DR 23/95, paragraph 4 of Article 126.º, in the absence of local experimental data or information of a similar nature, the infiltration flow value can be considered equal to the annual average flow in small conglomerate networks with collectors downstream up to 300mm in diameter. An infiltration flow value was considered identical to the domestic instantaneous flow rate.

The absence of industry or commercial services, as mentioned previously, will not be accounted for industrial and commercial flows.

HYDRAULIC DESIGN OF THE DRAINAGE WASTEWATER INFRASTRUCTURE

According to Sousa (2001), in a wastewater drainage network (WWDN) there are, from the Hydraulic and sanitary point of view, the following three features:

- The flow is done with a free surface, except in very special conditions.

- The flow regime is variable.
- Wastewater carries significant amounts of suspended solids and in solution (of organic and inorganic nature).

Always considering the conditions prescribed in the articles of the DR 23/95, the hydraulic design was made with Gauckler-Manning formulas for flow rates calculation. The collectors implementation was made checking the diameters, maximum and minimum slopes, flow speeds and height according to the legislation. In *Table 7* the requirements for the pipelines design are presented.

Table 7 – Conditions of implementation for the pipelines in DR 23/95.

Parameter	**Unit**	**Established limits in DR 23/95**
Maximum slope	[%]	15
Minimum slope	[%]	0,5
Maximum flow speed	[m/s]	3 (in the project horizon)
Minimum flow speed	[m/s]	0,6 (in the project horizon)
Minimum diameter	[mm]	200
Pipelines minimum depth	[m]	1,2
Flow height	[D/h]	For D≤500mm → 0,5 For D>500mm → 0,75

HYDRAULIC DESIGN OF PUMPING STATION

General Considerations

The topography prevents the flow drainage by gravity, and for that reason the construction of a lift system was considered. As a solution in the conduit lift, a pipe with 110mm of diameter and a minimum slope of $i \geq 0.5\%$ was chosen, ensuring a good flow and avoiding obstruction by liquid mass. There were some worries to place all the collectors of the system upward and avoid having lows, to ensure adequate ventilation with few accessories.

In the choice of place for the pumping station construction, special attention was paid in the integration with the existing system to minimize costs, the hydrogeological constraints, the distance from the electrical power supply source, the location of a possible emergency discharge and propagation effects of noise and vibration.

In the PS an arrival visit chamber was designed, also a well pump and a valve chamber, taking into account the size needed for operations and maintenance visits.

Hydraulic design of the pumping station

The depth of the well pump was determined taking into consideration the ground level of the affluent pipes, the height required for the pump installation in order to always keep the pump submerged, and the distance between maximum and minimum operation levels of the elevator group and the alarm level.

The group will consist of two lift pumps, one of them acting alone, twice per hour (two starts), and the second serving as a backup, in case of need or failure. The data from the solution adopted are presented in *Table 8*.

Quadro 8 – Well pump data

Parameter	Unit	Data
Pumped flow	[m3/s]	0,007
Useful Volume	[m3]	2,04
N.º of starts	[-]	2
Useful height	[m]	0,46

To choose a pump group the necessary characteristics of this were determinated. The lifting height of hydraulic pumps was obtained, the calculation of energy losses made along the pipeline with a throughput pumping of 7L / s, and the effects of hydraulic shock lift on the conduit were evaluated. After this the pressure variations were determinated in relation to power lines and the power required. The corresponding data is presented in *Table 9*.

Table 9 – Pump group necessary characteristics

Parameter	[Unit]	Value
Pipe lenght L	[m]	272,40
Total load downstream of the pump group	[m]	19,08
Breaktime of the pump group	[s]	1,35
Time phase	[s]	1,65
Time of maneuver	[-]	Quick
Pressure variation (in relation to power line static)	[m]	4,02
Overpressure referenced to the power line static	[m]	19,76
Underpressure referenced to the power line static	[m]	11,72
Power	[kw]	2,09

SEPTIC CONDITIONS AND HEALTH DESIGN

A large concentration of hydrogen sulfide causes intense and unpleasant odors, toxic environments, corrosion in sewers, visit chambers and other infrastructure and equipment, and, in exceptional circumstances, can lead to explosive atmospheres. The septic condition is thus associated to the formation of sulfides in the liquid mass.

In this project the drainage system is made in a free surface flow with a height less than half the diameter. The sulfides content does not reach very high values in the liquid mass due to absorption of oxygen in the liquid mass-air interface.

Calculation Model

With the expression of Pomeroy 1959, to calculate the concentration of sulfides in under pressure pipelines, the calculation of sanitary conditions in the PS was made, and the results are presented in *Table 10*.

Table 10 – Sulfides calculation

Parameter	[unit]	Value
Sulfides concentration	[mg/l.h]	1,56
Calculation Temperature	[º.C]	20
Flow	[m^3/s]	0,007

The obtained value exceeds 1.5 mg / l, and for that reason it is feared some health problems (the manifestation of unpleasant odor and the occurrence of corrosion) in the treatment and drainage structures that develop downstream. In the pressure pumping conduit, these problems do not occur, since there is no contact with the atmosphere and, therefore no conditions for the hydrogen sulfide. However means of protection were used, such as corrosion-resistant PVC pipes, epoxy paint in the visit chamber, and a slight gap in the PS arrival chamber to prevent the erosion of it.

PUMPING STATION STRUCTURAL DESIGN

Material

For the material options of the PS construction were taken into account the environmental exposure classes referred to in standard NP EN 206-1 and information referred to in the specification LNEC E 464 - 2007. The structure will be exposed to anaerobic bacteria attack that produce some acids, which is a highly aggressive chemical attack due to constant contact with the sewage, and for that reason the structure was included in an environmental class exposure XA3 (highly aggressive chemical environment). According to the considered class for this structure appropriate materials and coatings were chosen. The chosen materials are listed in *Table 11*.

Table 11 – Materials and coatings adopted in the pumping station.

Materials		[Unit]	Characteristics
Concrete	Resistance class	[-]	C35/45
	water/cement relation	[-]	0,45
	Cement dosage	[kg/m^3]	360
	Type	[-]	CEM IV/A*
	Nominal coating	[mm]	60
	$D_{máx}$	[mm]	25
Steel	Resistance class	[Mpa]	500
	Manufacturing process andherence	[-]	NR

Pumping station structural design

Due to the structure peculiarities, the concrete elements in contact with the outside must not crack, to prevent soil contamination by the wastewater. Because of this condition it has to be guaranteed that the concrete resists only in elastic regime. We can prevent the concrete cracking in any situation if we guarantee that the acting time is less than the critical moment of the material cracking.

To calculate the actuating efforts it was set different actions, namely:

- Dead weight of the structure;
- Liquid mass weight;
- Land impulse;
- Overload road;

With the help of the Bars tables the acting efforts were calculated, and to define the armor the reduced bending moment was determined. This reduced bending moment served to define the mechanical percentage of equivalent armor.

A slightly higher amount of reinforcement than necessary was chosen, putting up mesh armor (# 0.10 Ø8; Ø10 # 0.10) with reasonable diameters and reduced spacing, this way no kind of structural problem is anticipated.

ESTIMATED COSTS OF THE DESIGNED INFRASTRUCTURES

In the present project the solution budget was calculated. The budget overview is presented in *Tables 12* and *13*.

Table 12 – Budget overview.

Budget Overview	
Designations	**Price(€)**
Drainage network	
Construction site	18.816,22
Lifting and replacement of pavement	44.357,71
Land movement (pipes)	137.063,04
Pipes and accessories	191.371,01
Several	3.532,55
Pumping station	
Preparatory work and sealing	4.568,53
Well pump and valve chamber	21.805,45
Lifting conduit	3.053,65
Total	**424.568,17**

Table 13 –Project Cost per lenght unit of pipe

Total network lenght [m]	**Project total cost [€]**	**Project cost per lenght unit of pipe [€/m]**
4906,32	424.568.17	**86,535**

FINAL CONSIDERATIONS

This work had as main purpose the design of a separative drainage network of wastewaters in the Paraduça village. For this project topographic data of this region were provided a priori. However a collection of updated information about the population was needed. A number of INE publications were consulted and a recognition of the city and surrounding region was made. This research allowed us to design a possible solution, using the skills development in Civil Engineering.

In the solution presented, all the requirements in the current regulations were taken into account, both within the drainage system and the structure of the pumping station, making this project a viable solution.

During this project the solution viability and the economic cost were constantly considered. The implementation and design of the network were made based on current regulations, and always having into account the costs of the adopted solution.

In addition to the aspects already mentioned, was taken into consideration the durability of the solution, and the network was dimensioned for a project horizon of 40 years and the pumping station structure to a service life of 50 years. Because of this the exposure of the structure to aggressive agents was considered, the toxicity level of WW in the lifting ducts was analyzed, and armoured materials and coatings were suitable to the surrounding environment.

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