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Infiltration well as compensatory measure of urban drainage: A financial analysis

Pozo de infiltración como medida compensatoria para el drenaje urbano: un análisis financier

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Abstract: The growth of cities generates a waterproofing of soils, causing much of the rain to seep off superficially. To remove this flow as soon as possible from the urban perimeter, urban drainage works are carried out. As in Brazil, conventional drainage techniques still predominate, in which the flow is transferred to the downstream points of the basin, these over time become inefficient, thus generating the need for the adoption of compensatory measures, among which we can mention the infiltration well. In view of the above this article aims to size an infiltration well for different areas of capture and perform a financial analysis of the construction of these devices. Four catchment areas (100 m², 250 m², 500 m² and 1000 m²) were adopted in the city of Aracaju/SE and for the sizing of the well was used a method adapted from Carvalho Júnior (2020). Wells with total depth ranging from 1.15 m to 6.10 m were obtained, and construction costs ranged from R$ 2,465.95 to R$ 8,697.53. Based on the results obtained, it is concluded that the sizing method applied is easy to apply, but implies larger wells, and finally, the replacement of concrete rings by another type of coating, can reduce the total cost for execution.
Keywords: *Costs; Withholding tax; flood reduction.*

Resumen: El crecimiento de las ciudades genera la impermeabilización del suelo, lo que provoca que gran parte de las precipitaciones se escurran por la superficie. Para retirar este escurrimiento lo más rápido posible del perímetro urbano, se ejecutan obras de drenaje urbano. Como en Brasil aún predominan las técnicas convencionales de drenaje, en las cuales el escurrimiento es transferido para los puntos aguas abajo de la cuenca, éstas con el tiempo se tornan ineficientes, generando así la necesidad de la adopción de medidas compensatorias, entre las cuales podemos citar el pozo de infiltración. Dado lo anterior, este trabajo tiene como objetivo dimensionar un pozo de infiltración para diferentes zonas de captación y realizar un análisis financiero de la construcción de estos dispositivos. Se adoptaron cuatro áreas de captación (100 m², 250 m², 500 m² y 1000 m²) en la ciudad de Aracaju/SE y para el dimensionamiento del pozo se utilizó un método adaptado de Carvalho Junior (2020). Fueron obtenidos pozos con profundidad total que varió de 1,15 m a 6,10 m, y los costos de construcción variaron de R$2.465,95 a R$8.697,53. Conclui-se que o método de dimensionamento aplicado é de fácil aplicação, mas implica em poços de maiores dimensões, e por fim, a substituição de anéis de concreto por outro tipo de revestimento, poderá reduzirá o custo total para execução.
Palabras clave: *Costes; Retención en origen; Reducción de inundaciones*.

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INTRODUCTION

According to the National Information System on Basic Sanitation (SNIS, 2021), rainwater should drain superficially through natural paths to reach the lowest points of the watersheds. However, the cities alter this natural environment, so as to interfere with the natural cycle of water drainage, causing the need for intervention, seeking to minimize the impacts that hydrological events can cause due to human anthropic action, which leads to the adoption of control measures, composed of structural actions, which are physical interventions; and structuring actions, such as guidelines, legal standards, inspection and education.

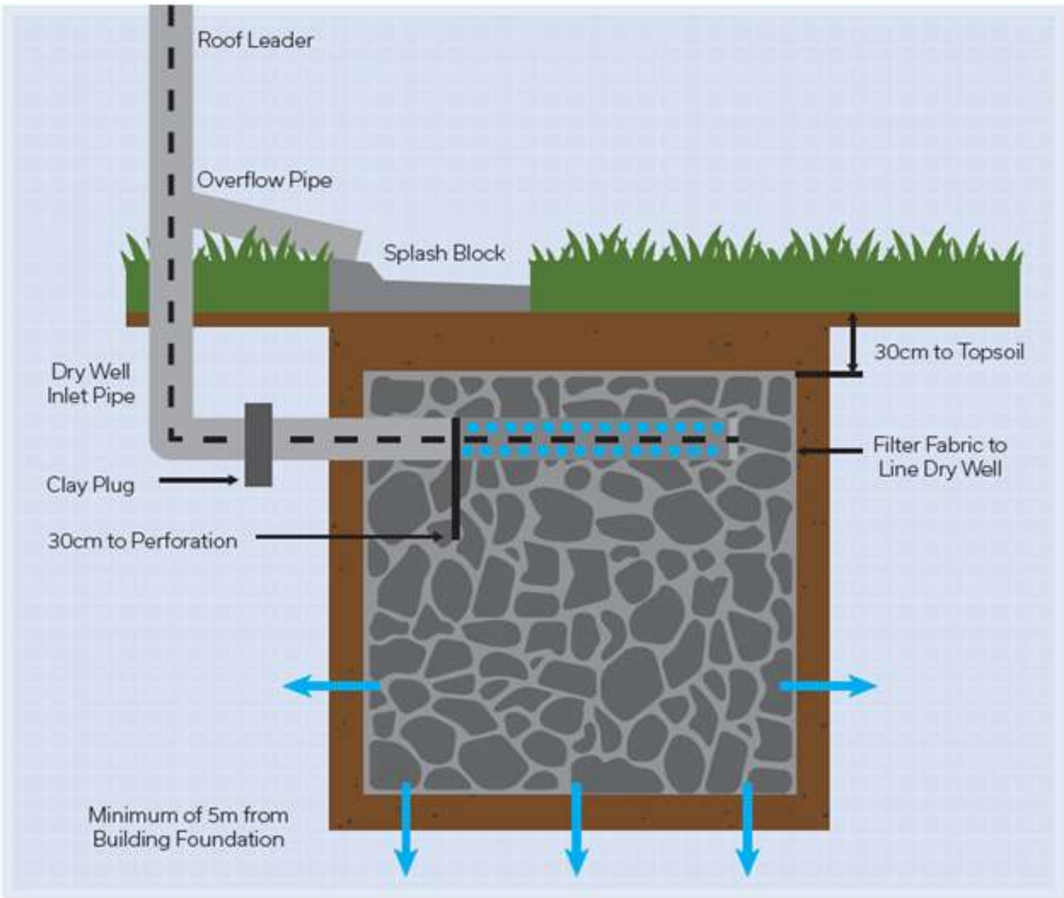
The goal of urban drainage is to remove rainwater runoff as quickly as possible from the urban perimeter, avoiding damage to the city and ensuring that there are no impacts to water bodies, the recipients of stormwater (ANA, 2002). According to Silva et al. (2019), the concept of urban drainage is conditioned to the ancient practices of dealing with the problem of stormwater in cities, which results in the procedure of rainwater harvesting, seeking that this procedure occurs as quickly as possible, efficiently to avoid damage.

In Brazil, conventional drainage techniques still predominate, in which the runoff is transferred to the downstream points of the basin (CALIL, BERNARDI, RIGHES; 2016). Modernly, several actions have been adopted in order to contain or mitigate the generation of urban floods, which are called compensatory techniques.

Compensatory techniques present a concept of sustainable drainage, which seeks to reduce the impacts that the urbanization process causes on the hydrological cycle (GONZALEZ, 2014). If the drainage system fails, the city will suffer from flooding and this shows how important storage measures become to reorganize runoffs and mitigate problems (CANHOLI, 2014). According to Lisboa (2019), there are numerous compensatory techniques that can be used to help control floods, and the most widespread ones have a focus on storage measures (detention, retention, and in-lot reservoirs) and infiltration measures (green roof, infiltration trench, permeable sidewalk, infiltration trench, infiltration well, among others).

The infiltration well consists of a well, as a wall of perforated concrete pipes or solid brick masonry in screen coated externally with geotextile blanket and filled with gravel No. 1 on the sides (interface blanket - soil), and a layer of gravel of 30 cm also coated (CARVALHO JÚNIOR, 2020). Its function is to infiltrate rainwater, in order to dampen the peaks of flow that may reach the conventional drainage system and, consequently, reduce the volume of direct surface runoff by retaining the excess volume of rainfall in the soil (BARBASSA; SOBRINHA; MORUZZZI, 2014).

FIGURE 01: Infiltration Well.



SOURCE: Windsor.com (2023).

The water table level also represents an important variant that influences the definition of the well geometry, and may even make its use unfeasible (SANTOS; CALVARIO, 2021). Martins (2017) apud Santos and Calvario (2021) points out minimum distances from the bottom of the reservoir to the water table, with values between 1.00m and 3.00m. A minimum distance of 1.5 m from the water table is the indication NBR 13969:199 (ABNT, 1997). It is recommended that the wells be built at least 1.50 meters away from other buildings, to avoid structural instability caused by infiltration or excavation of the well, and it is also necessary to conduct geotechnical surveys to identify the profile and height of the water level (SANTOS; CALVARIO, 2021). Given the above, this article aims to size an infiltration well for different catchment areas and perform a financial analysis for implementation of this device.

THEORETICAL FOUNDATION

The occupation of urban areas increases the sealing of built areas generating increased surface runoff, which causes a higher frequency of urban flooding (REIS; ILHA, 2014). According to these same authors, one way to reduce the impact caused by occupation are the compensatory technical solutions, based on stormwater infiltration techniques, which have been widely proposed for building systems projects.

Urban drainage systems modernly designed with environmental protection concepts prioritize the maintenance of the water balance existing during the pre-urbanization period; one of the solutions adopted is the introduction of drainage systems at the source that aim to restore the water balance balance in the area to be occupied by inducing infiltration of rainwater, in addition to the reduction and retention of surface runoff (REIS; OLIVEIRA; SALES, 2008).

One of the ways to induce rainwater infiltration is through infiltration wells. According to Barbassa; Sobrinha and Moruzzi (2014) these wells are systems widely employed in Europe and the USA, being a micro-scale technological alternative whose function is to retain rainwater at the expense of the runoff parcels. It is a compensatory technique called punctual (small area in plant), which aims to mitigate the effects of direct runoff in its generation and can also be designated as a control technique of direct runoff at the source, given that, by allowing the infiltration of water into the ground dampens the peaks of flow and, consequently, reduces the volume of direct runoff (BARBASSA; SOBRINHA; MORUZZZI, 2014).

The design of compensatory techniques, such as the infiltration well, should consider the characteristics of the soil, as this is who will receive the rainwater being its outlet, evaluate the possibility of contamination of the groundwater aquifer and avoid sanitary problems; the constructive aspects, such as support material of the walls and its permeability, the existence or not of pre-treatment upstream of the well and the distribution of water through the walls that can affect the performance of the well (CARVALHO, 2008; BARBASSA et al, 2014; REIS et al., 2008); BATISTA et al, 2005 apud FERREIRA; BARBASSA; MORUZZZI, 2018).

The infiltration wells can be built with perforated concrete rings, surrounded on the sides and base by gravel and geotextile blanket that acts as a filter that retains particulate material, pipe to bring the water from the impermeable areas and overflow connected to the public drainage system or gutter (SILVIERO, 2008). Reinforcing this need for the use of gravel on the side Ferreira; Barbassa; Moruzzi (2018) report that studies show that rainwater infiltration occurs better when using a percolation area on the walls and base having gravel on the sides and bottom and geotextile blanket surrounding the entire well.

Among the advantages in the use of this device, we mention the reduction of pressure in the conventional drainage system by reducing the volumes drained by the conventional drainage system, financial gain by reducing the conventional drainage system, low value for design and deployment, groundwater recharge, contribution to the development of vegetation around the well and the ability to be deployed in the most varied topographies (CASTRO, 2002 apud ANTOS; CALVÁRIO; SOUZA, 2021).

Among the disadvantages are: the possibility of clogging the walls and bottom of the wells that can hinder infiltration; the risk of groundwater contamination, especially in sandy soils and high water table; and the saturation of hydraulic conductivity around the well, interfering with its ability to infiltrate water into the soil (ARAUJO, 2010). (CASTRO, 2002; MARTINS, 2017; BARBASSA; FERREIRA; MORUZZZI, 2018 apud SANTOS; CALVÁRIO; SOUZA, 2021).

METHODOLOGY

Study area

The city of Aracaju/SE will be used. For financial analysis of the well construction costs four areas will be adopted (100 m², 250 m², 500 m² and 1000 m²), dimensioned one well for each, and finally, a budget estimate will be done.

Sizing of the infiltration well

To size the well, a method adapted from Carvalho Júnior (2020) described below will be adopted:

i) Initially the design flow rate will be calculated determined by the equation below:

$$Q = (C \times I \times A)/60 \quad (1)$$

Where: C = runoff coefficient (adopted equal to 1), i = rainfall intensity (mm/h) for a return period of T=1, adopted as 116mm/h for Aracaju according to NBR 10844 (ABNT, 1989); A = catchment area (m²) and Q = flow (L/min).

ii) Calculate the total volume precipitated over the contribution area according to equation 2 below:

$$V_{prec} = Q \times t \quad (2)$$

Where: V_{prec} = volume (Liters); Q = design flow rate (L/min) and t = time (minutes). The time of 5 minutes will be adopted, because according to Carvalho Júnior (2020) this value is able to reduce the flood peak;

iii) Calculate the useful depth according to equation 3, below:

$$H_{utile} = 4V/\pi d^2 \quad (3)$$

Where: H_{useful} = useful depth (m); V = total precipitated volume (m³) calculated with equation (2) and, d = diameter of the concrete rings (in this article we will adopt concrete rings with d = 1.50 m).

iv) Determine total depth, which the sum of the useful depth plus 30 cm of the gravel layer, and an upper clearance of 30 cm;

v) In possession of the dimensions of the people, carry out the quantitative survey of the construction services of the device (excavation, concrete rings, gravel layer and concrete cover);

vi) Based on the prices indicated by SINAPI, calculate the construction costs of the dimensioned wells.

RESULTS AND DISCUSSIONS

Dimensions of the infiltration wells

Following the method presented above, and considering the different coverage areas, the dimensions presented in Table 01, below, were obtained:

TABLE 01: Dimensions of the infiltration wells.

Adopted Diameter (m)	Useful Depth (m)	Total Depth (m)
Well dimensions for a catchment area 100 m²		
1.50	0.55	1.15
Well dimensions for a catchment area 250 m²		
1.50	1.40	2.00
Well dimensions for a catchment area 500 m²		
1.50	2.70	3.30
Well dimensions for a catchment area 1,000 m²		
1.50	5.5	6.10

SOURCE: Survey data (2022).

A direct relationship is observed between the catchment area, the volume of the infiltration well and its dimensions (diameter and depth). In our study, with we chose to keep the same diameter, the larger the catchment area, the larger the well volume and consequently the greater the depth. When the water table is a limiting agent, there are two possible solutions, increase the diameter and decrease the depth, or execute more than one well.

Quantities of services and budget estimate

In this stage of the work, based on the well dimensions, the quantities of excavation volume, concrete rings, gravel volume, geotextile blanket and concrete cover will be determined. Finally, the prices will be researched at SINAPI - Sistema Nacional de Pesquisa de Custos e Índices da Construção Civil. The results obtained are presented in Tables 2, 3, 4 and 5, below:

TABLE 02: Cost estimate for infiltration well with catchment area 100 m².

Service	Unit	Quantity	Unit Cost	Total Cost
Manual excavation	m³	4	17.91	71.64
Concrete rings	Unid.	3	634.39	1,903.17
Gravel	m³	2.48	26.06	64.63
Concrete cover	m²	3.46	123.27	426.51
			Total Sum	2,465.953

SOURCE: Survey data (2022).

TABLE 03: Cost estimate for infiltration well with catchment area 250 m²

Service	Unit	Quantity	Unit Cost	Total Cost
Manual excavation	m³	6.8	17.91	121.79
Concrete rings	Unid.	4	634.39	2,537.56
Gravel	m³	3.87	26.06	100.85
Concrete cover	m²	3.46	123.27	426.51
			Total Sum	3,186.714

SOURCE: Survey data (2022).

TABLE 04: Cost estimate for infiltration well with catchment area 500 m²

Service	Unit	Quantity	Unit Cost	Total Cost

Manual excavation	m³	11.6	17.91	207.76
Concrete rings	Unid.	7	634.39	4,440.73
Gravel	m³	6.19	26.06	161.31
Concrete cover	m²	3.46	123.27	426.51
			Total Sum	5,236.312

SOURCE: Survey data (2022).

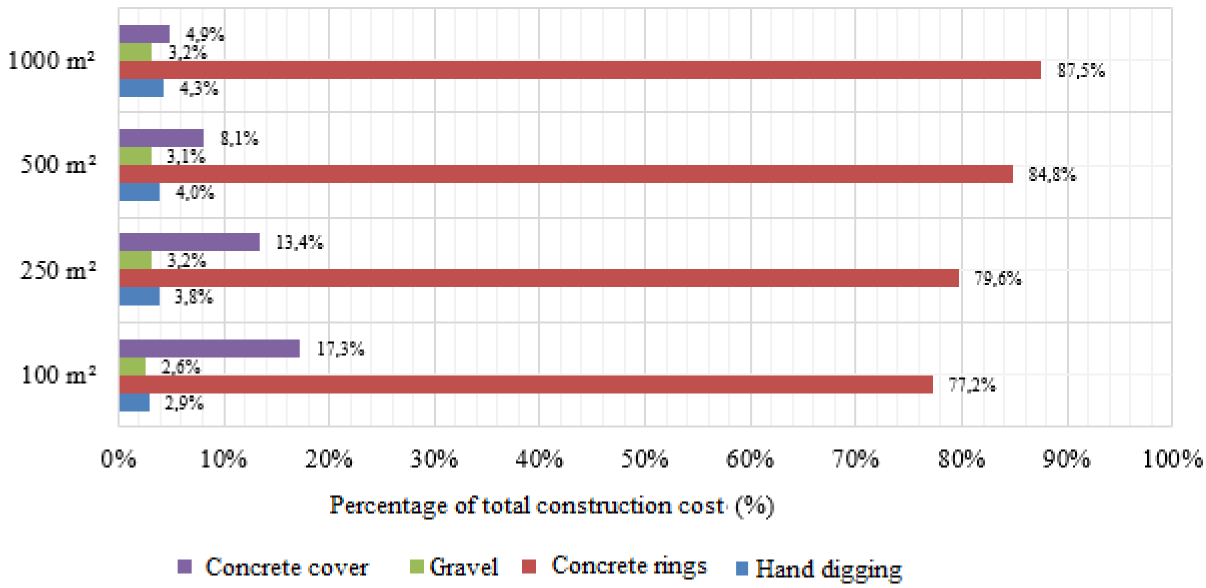
TABLE 05: Cost estimate for infiltration well with catchment area 1.000 m²

Service	Unit	Quantity	Unit Cost	Total Cost
Manual excavation	m³	21	17.91	376.11
Concrete rings	Unid.	12	634.39	7,612.68
Gravel	m³	10.83	26.06	282.23
Concrete cover	m²	3.46	123.27	426.51
			Total Sum	8,697.534

SOURCE: Survey data (2022).

Aiming at a more detailed analysis, Graph 01 was made for the different infiltration wells, indicating the percentage of each construction item in the final cost, presented below.

CHART 01: Percentage of contribution of services in the construction of an infiltration well.



SOURCE: Survey data (2022).

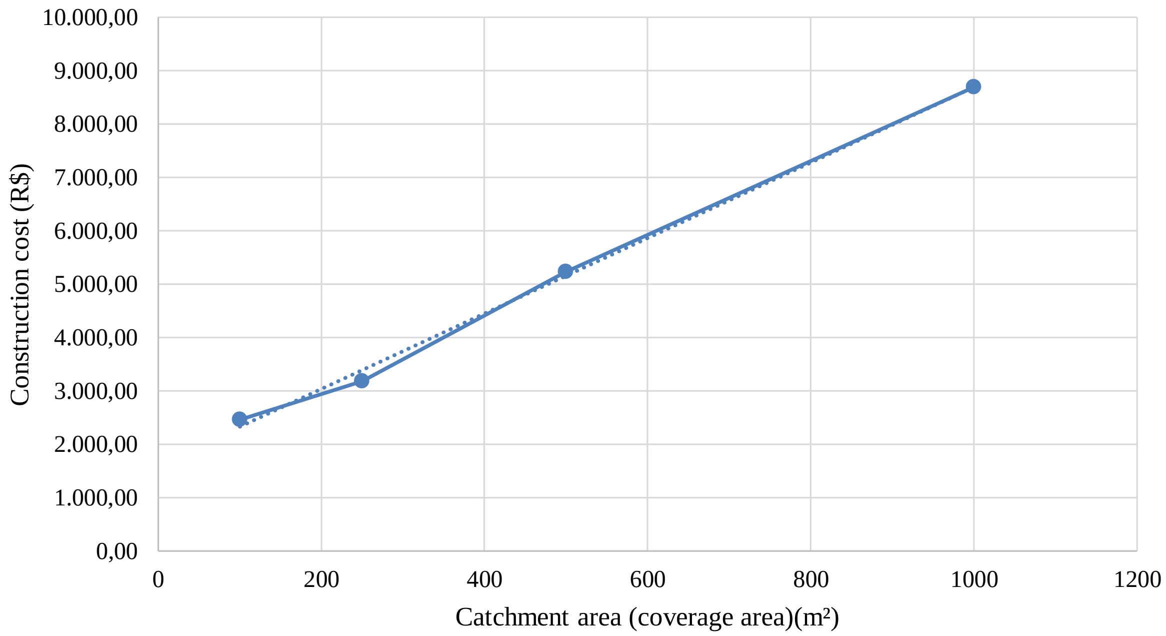
It can be seen that the item with the greatest impact on costs are the concrete rings, whose percentage ranged from 77.2% to 87.5%, with a tendency for their impact on construction to increase the larger the well to be built. It is indicated, to verify in each case individually, the possibility of using masonry as a coating for the well, aiming to reduce costs.

The second item with the greatest impact was the reinforced concrete cover, varying from 17.3% to 4.9%. In this simulation specifically, as the same diameter was adopted, the cost was the same for the four wells, but its percentage in the construction cost decreases as the well increases, because the other items have their costs increased.

The two items with the least impact were gravel (2.6% to 3.2%) and excavation (2.9% to 4.3%). Both have their cost increased as the well dimensions increase, but proportionally to the total cost their percentage grows shyly, in view of the impact of the concrete rings on the final construction cost.

Finally, when relating the well's catchment area with its execution costs, it can be seen that there is a practically linear relationship between two values, according to Graph 02, below.

CHART 02: Relationship between catchment area (m²) and construction cost (R$) of infiltration wells.



SOURCE: Survey data (2022).

CONCLUSIONS

We conclude that: a) The design used in this work is easy to apply, because it is not necessary to perform tests to determine the soil infiltration coefficient; b) Considering the soil as impermeable, in the design process, results in a well with larger dimensions and, consequently, higher execution costs; and c) Since the lining of the well (precast concrete rings) is the item that accounts for most of the costs, an alternative to cheapen the devices would be to use other linings, whenever possible.

REFERENCES

[1] AGÊNCIA NACIONAL DE ÁGUAS (ANA). **Manual de drenagem urbana**. Brasília: ANA, 2002.
ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 13969: **Tanques sépticos - Unidades de tratamento complementar e disposição final dos efluentes líquidos - Projeto, construção e operação.** 1 ed. Rio de Janeiro: ABNT, 1997. 60p.

[2] BARBASSA, A. P.; SOBRINHA, L. A.; MORUZZI, R, B. **Poço de infiltração para controle de enchentes na fonte: avaliação das condições de operação e manutenção**. Ambiente Construído, [S.L.], v. 14, n. 2, p. 91-107, jun. 2014. FapUNIFESP (SciELO). http://dx.doi.org/10.1590/s1678-86212014000200007.

[3] CALIL, V. S.; BERNARDI, E. C. S.; RIGHES, A. A. **Impacto da utilização de telhados verdes no escoamento superficial do Arroio Esperança em Santa Maria – RS.** Disciplina rum Scientia Série: Naturais e Tecnológicas, Santa Maria, v. 15, n. 1, p.1-16, 2016.

[4] CANHOLI, A. P. **Drenagem urbana e controle de enchentes**. 2. ed. São Paulo: Oficina de Textos, 2014.

[5] CARVALHO JÚNIOR, R. de. **Instalações Prediais Hidráulico-Sanitárias**: princípios básicos para elaboração de projeto. 4. ed. São Paulo: Blucher, 2020.

[6] GONZALEZ, F. C. G. **Projeto de drenagem sustentável para mitigação de cheias na bacia do rio Quitandinha, em Petrópolis, RJ.** Rio de Janeiro, 2014. 89 f. Trabalho de Conclusão de Curso. (Bacharelado em Engenharia Ambiental) – Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2014.

[7] SANTOS, A. A. M. dos; CALVARIO, A. C. do. **Sistemas compensatórios de drenagem urbana: um estudo sobre a aplicabilidade de poços de infiltração**. 2021. 50 f. TCC (Graduação) - Curso de

Pós-Graduação em Engenharia de Infraestrutura, Campus Vitória, Instituto Federal do Espírito Santo, Vitória, 2021.

[8] SILVA, B. L. A; OLIVEIRA, I. C. A; BUENO. L. L. N; SILVA, T. P. D; RODRIGUES, J. C. S; AMARANTE, M. S. **Conjunto de drenagem urbana nas cidades e sua importância na redução de inundações e enchentes.** Revista Pesquisa e Ação, v. 5, n. 2, p. 205-227, 2019.

[9] SINS - SISTEMA NACIONAL DE INFORMAÇÃO SOBRE SANEAMENTO (2021). **Diagnóstico temático Drenagem e Manejo das Águas Pluviais – Visão Geral Ano de Referência 2020**. MDR/SNS, Brasília, 2020.

[10] REIS, R. P. A.; OLIVEIRA, L. H. de; SALES, M. M. **Sistemas de drenagem na fonte por poços de infiltração de águas pluviais**. Ambiente Construído, Porto Alegre, v. 8, n. 2, p. 99-117, 2008. Disponível em: https://repositorio.bc.ufg.br/. Acesso em: 31 out. 2022.

[11] REIS, R. P. A.; ILHA, M. S. de O. **Comparação de desempenho hidrológico de sistemas de infiltração de água de chuva: poço de infiltração e jardim de chuva.** Ambiente Construído, [S.L.], v. 14, n. 2, p. 79-90, jun. 2014. FapUNIFESP (SciELO). http://dx.doi.org/10.1590/s1678-86212014000200006.

[12] FERREIRA, T. S.; BARBASSA, A. P.; MORUZZI, R. B. **Controle de enchentes no lote por poço de infiltração de água pluvial sob nova concepção**. Engenharia Sanitaria e Ambiental, [S.L.], v. 23, n. 3, p. 437-446, jun. 2018. FapUNIFESP (SciELO). http://dx.doi.org/10.1590/s1413-41522018161116.

[13] SANTOS, A. A. M. dos; CALVÁRIO, A. C. do; SOUZA, J. F. de. Si**stemas compensatórios de drenagem urbana : estudo sobre a aplicabilidade de poços de infiltração**. 2021 49 p. Trabalho de Conclusão de Curso (Especialização) - Pós-Graduação em Engenharia de Infraestrutura Urbana, Instituto Federal do Espírito Santo, Vitória, 2021.