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Potential savings of potable water due to the use of rainwater in a shopping mall in Recife/PE

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ABSTRACT

Water is one of the world's most valuable resources and indispensable for human survival. Given this, climate change and population growth generate an increase in demand for water resources, leading to water scarcity. The use of rainwater is a measure that mitigates environmental impacts, contributes to the retention of rainwater and reduces the demand for drinking water. Therefore, water scarcity stimulates the development of alternatives for water conservation. The objective of this study is to estimate the potential savings of potable water to be replaced by rainwater for non-potable use in a shopping center building in the Northeast of Brazil. The methodology consisted in simulating the volume of the reservoir for storage of collected rainwater. A study of the rainfall indexes and their periodicity was carried out, evaluating the months with highest and lowest precipitation. Subsequently, the Neptune computer program was used to determine the volume of the reservoir. To this end, a study was carried out with different catchment areas, in order to define the area that offers the best potential for supplying the water demands. The results indicated that the most suitable reservoir volume is 117 m³, with potential savings of 6.02% for drinking water and a complete and partial supply of 52.56% for rainwater demand. It was concluded that the potential for drinking water savings justifies the implementation of a rainwater harvesting system in a project of this size, proving to be technically feasible.

KEYWORDS: Rainwater use. Non-potable use. Shopping mall.

1 INTRODUCTION

Water is indispensable for human survival; however, in many situations, this valuable resource is not available in acceptable quantity and quality due to natural constraints, lack of infrastructure, or a combination of both (PINTO; MARQUES, 2017). Climate change, population growth, and complex economic activities generate increased demand for water resources, compromising the flows and quality of the world's large freshwater ecosystems (LIU *et al*., 2018; AGHAKOUCHAK *et al*., 2021; UNFRIED *et al*., 2022).

The urbanization process leads to soil sealing in large cities, altering the hydrological cycle, generating floods, insufficient recharge of aquifers, and changes in water quality (GALVÃO *et al*., 2022; VANEGAS-ESPINOSA *et al*., 2022; WANG *et al*., 2014). Therefore, increasing water demand exacerbates the stress on surface and groundwater resources (AGHAKOUCHAK *et al*., 2021). Withdrawals in regions that already have water scarcity will impose further pressure on the renewable water resource base, threatening the long-term availability of freshwater in the various economic activities dependent on this resource (NECHIFOR; WINNING, 2018).

It should be noted that the intense population growth that has occurred in recent decades directly impacts the natural water dynamics of large urban centers. The scarcity of water resources is considered a serious threat to human survival and has the ability to restrict the development of a country's national economy, as well as becoming a strategic concern worldwide (HASHIM *et al*., 2013; ZHANG *et al*., 2019). According to the United Nations population growth projections (UN, 2022), the population is estimated to increase from 7.9 billion, recorded in 2021, to 8.5 billion in 2030 and 9.7 billion in 2050. Therefore, this population growth can further aggravate the global water supply crisis.

In view of this, the conscious use of water becomes essential. Thus, it is understood that water conservation is associated with the controlled and efficient use of water, as well as measures for rational use and reuse. Water conservation practices are ways to improve and regulate water demand and supply without compromising the supply of water bodies and environmental protection (BOCANEGRA-MARTÍNEZ *et al*., 2014; GOIS *et al*., 2015).

Rainwater harvesting practices are also considered a viable strategy for the sustainability of water resources in urban centers, as they can contribute not only to the interception and storage of rainwater, significantly dampening flood peaks, but also to the conservation of drinking water, since a rainwater harvesting system intended for alternative water use for non-potable purposes is an important tool for water conservation in buildings (PIMENTEL-RODRIGUES; SILVA-AFONSO, 2022).

The Brazilian Association of Technical Standards (ABNT), updated in 2019 the Brazilian standard NBR 15.527/2019, which addresses the use of rainwater from roofs for non-potable purposes, such as irrigation of areas for landscaping purposes; toilet flushing; floor cleaning; cooling systems; fire technical reserve; vehicle washing.

With regard to water consumption in shopping malls, this type of building is usually characterized by having high water consumption in non-potable end uses, such as in cooling towers, cleaning services, in garden irrigation and toilet flushing, demonstrating a high potential for the use of rainwater (LEE *et al*., 2016; SOUSA; SILVA; MEIRELES, 2017).

Flooding is the greatest environmental challenge for cities, so the rainwater reservoir can play a crucial role in reducing the propensity to flooding (SEPEHRI *et al*., 2018). According to Silva Junior, Silva and Alcoforado (2016), the city of Recife, Pernambuco-Brazil, the location of this object of study, faces an unfavorable scenario due to the fact that it has a drainage system highly vulnerable to tidal oscillations, making the use of reservoirs an essential alternative for the reduction of flood peaks and consequently flooding.

In this perspective, rainwater harvesting has been identified as an alternative source of non-potable water for the sustainable management of water resources (SOUSA; SILVA; MEIRELES, 2017; BINT *et al*., 2018; YANNOPOULOS *et al*., 2019). Rainwater harvesting systems are able to mitigate the problem of water scarcity, reducing dependence on water supply and the impacts of flooding, in view of the reduction of surface runoff (HASHIM *et al*., 2013; SAMPLE; LIU, 2014; MORALES-PINZÓN *et al*., 2015, SEPEHRI *et al*., 2018).

2 OBJETCIVE

The objective of this study was to estimate the potential savings of potable water to be replaced by rainwater for non-potable use in a shopping center building in the Northeast of Brazil.

3 METHODOLOGY

The methodological procedure of this work consisted in the study of computer simulation using the computer program Neptune 4.0, to evaluate the potential for drinking water savings and the sizing of upper and lower reservoirs for rainwater storage in a shopping center building that has a rainwater collection network project. Rainwater was considered for non-potable uses, such as toilet and urinal flushing, bathroom cleaning and garden irrigation.

3.1 Characterization of the object of study and data collection

The first stage of the work consisted of characterizing the enterprise, evaluating the architectural project and the hydraulic/sanitary installations project, among others. Then, data were collected regarding the maximum number of users that frequent the building and the activities that consume water.

After collecting the data, the pluviometric station was identified and the historical pluviometric series was surveyed. The rainfall data were obtained from the data made available by the Pernambuco Water and Climate Agency (APAC), referring to the rainfall station that is located closest to the building and that had the most extensive historical series of rainfall data. The rainfall data includes information about daily precipitation from 01/01/2000 to 12/31/2020.

3.2 Estimation of water demand

The building's consumption of potable water was estimated based on monthly monitoring, performed through readings of the building's hydrometers and through the analysis of consumption histories provided by the mall's administrative sector, from January 2012 to December 2021.

The activities that consume non-potable water in the building and can use rainwater collected from the existing rainwater collection network are garden watering, washing bathroom floors, flushing toilets and urinals, and supplying the central cooling system. To estimate the water consumption for garden irrigation, we considered a water consumption of 2 L/day/m², according to criteria pointed out by Tomaz (2010). It was considered that irrigation is performed daily, considering 30 days of irrigation per month.

To estimate the water consumption for washing bathroom floors, we also adopted a water consumption of 2 L/day/m², according to TOMAZ (2010). Only the floor washing of the bathrooms used by customers and employees was considered; in this estimate, it was considered that the floor washing would be done once a day, totaling 30 days per month.

To estimate the consumption of water to supply the demand of the cooling center, we considered the volume of water lost and the number of days in the month that the volume of water demanded by the cooling center is supplemented, in order to maintain the water level pre-set by the manufacturer of the equipment. The volume of water was verified in the replacement history provided by the administrative sector of the mall, between the period 2018 and 2021. Thus, it was considered in this work that the replacement of water in the central cooling occurs daily. Then, the daily average of such consumption was multiplied by 30 days of the month.

As for water consumption to supply the building's toilets and urinals, hydrometers were installed to measure the specific water demand of each type of toilet in a model bathroom. Thus, with the history of water consumption by type of toilet appliance, the average daily consumption of each toilet bowl and urinal was verified, according to (GUZZO, 2017).

The volume of water demanded by a toilet in m³/day was obtained by dividing the total volume of water measured from the toilet bowls by the number of bowls in the bathroom. As well as, the volume of water demanded by a urinal in m³/day was obtained by dividing the total volume of water measured from the urinals by the number of urinals in the bathroom. Then, the daily average per type of sanitary appliance was multiplied by the total number of sanitary appliances in the building. Subsequently, the daily average of such consumption was multiplied by 30 days in the month.

3.3 Dimensioning the catchment area

A study of the building typology was carried out in order to find out the roof areas that would allow rainwater collection, considering aspects such as the layout, type, and inclination of the roofs, as well as the existence of gutters and collectors.

The coverage area was extracted from the architectural project, made available by the mall administration. For the purpose of calculating the catchment area, it was considered in the work only the coverage areas, being discarded the areas of the external patios, due to the accumulation of impurities, debris, leaked materials of vehicles, such as greases, fuels and others. All surfaces are horizontal, being the calculation of the contribution area carried out through NBR 10.844 (ABNT, 1989).

In the determination of the catchment area, an analysis of the cover plants of the building and simulations in the computer program Neptune, in order to verify if the maximum catchment area would be necessary to compose the system and meet the demand for non-potable water of the building or only part of it.

For dimensioning the volume of rainwater to be collected, it is necessary to know the characteristics of the contribution area and the surface runoff coefficient of the cover called Runoff coefficient. The identification of the type of coating of the contribution area was performed by means of on-site inspection, for later determination of the surface flow coefficient. Considering that part of the roof of the mall is in concrete (uncovered waterproofed slab) and part in metal tiles, a flow coefficient equivalent to 0.90 was adopted.

3.4 Dimensioning of rain water reservoir

The computer program Neptune 4.0 was used to simulate the water reservoir design. Neptune is a computer program developed by LabEEE (Laboratory of Energy Efficiency in Buildings) of the Federal University of Santa Catarina, which aims to determine the potential for saving drinking water as a function of reservoir capacity, using rainwater for non-potable uses (GHISI; CORDOVA, 2014). The Neptune enables the simulation of various capacities for the lower rainwater reservoirs, indicating the ideal volume for maximum economy.

The input data for the program are: the catchment area, the daily historical series of rainfall data, the initial rainfall discharge, the daily demand for drinking water, the number of users of the building, the runoff coefficient and the percentage of total demand to be replaced by rainwater

To define the volume of the lower reservoir, starting from the maximum volume, simulations were performed in the Neptune computer program, with reservoir volumes varying in intervals of 1,000 liters. For each simulation performed, the potential for drinking water savings was verified, concluding the simulations when the tested reservoir volume reached an increment equal to or less than 0.5% of drinking water savings over the potential generated by the previous simulation, as proposed by (MARINOSKI, 2007).

In a rainwater harvesting system there may or may not be an upper and lower reservoir. For this study, the existence of both was considered, since the building has a predefined location for the implementation of the upper reservoir, as well as exclusive existing pipes for feeding the branches and sub-branches of the toilets and urinals, by gravity. Therefore, the volume of the upper reservoir will be equal to the average daily rainwater demand. For both storage reservoirs, the initial runoff disposal volume used was adopted according to NBR 15.527 (ABNT, 2019).

3.5 Analysis of monetary economics

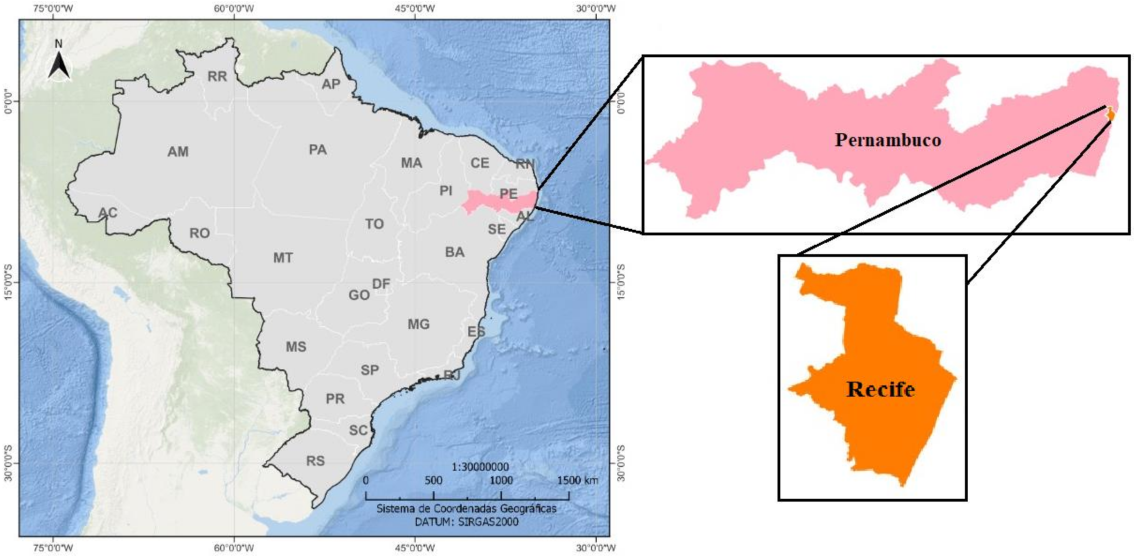
To determine the monthly monetary savings after the implementation of the system, in R$/month, it was considered the potential savings generated by the simulation in the computer program Netuno and the water consumption tariff charged by the water utility company, Pernambuco Sanitation Company - COMPESA, in its tariff structure for the year 2021 (ARPE, 2021). The annual monetary savings, in R$/year, was obtained from the monthly monetary savings multiplied by the number of months in the year.

4 RESULTS AND DISCUSSIONS

4.1 Characterization of the enterprise and estimates of demands

The building under study is located in the city of Recife, Pernambuco - Brazil, as shown in Figure 1. The municipality extends over 218.5 km² and is neighbor to the municipalities of Olinda, Camaragibe and Jaboatão dos Guararapes. Recife is located in the geographical coordinates of latitude 08°3'15" S and longitude 34°52'53" W, at an altitude of 7 meters. Recife is the capital of the State of Pernambuco.

Figure 1: Map of Brazil, map of the State of Pernambuco. In highlight the city of Recife



Source: Prepared by the authors based on IBGE, 2021.

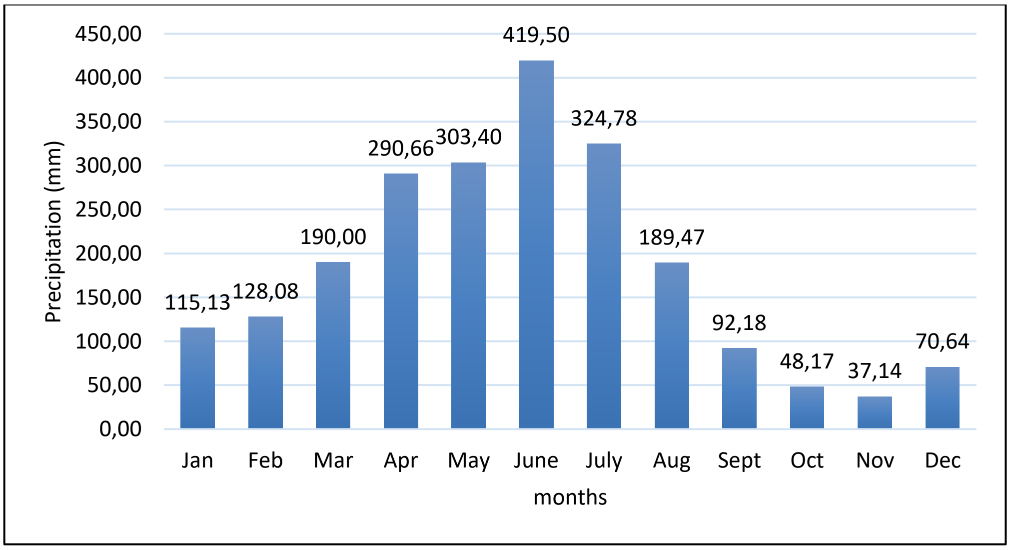
The first shopping malls in Pernambuco, opened in 1980, the Recife Shopping Center has a gross leasable area of 90,791 m², total constructed area of 176,047 m², and is inserted in a land area of 185,301.77 m². The building received an average of 52,300 people per day between 2012 and 2021, has 450 stores, 5,800 parkings spaces and 14 movie theaters, with capacity for up to 3,000 people.

4.2 Rainfall data

To input rainfall data into the Neptune Computational Program to determine the catchment area and volume of the storage reservoir, the daily historical rainfall series from 01/01/2000 to 12/31/2020 was used, since the program requires the input of daily rainfall from the longest possible period. Data from the climatological station of Recife, operated by the National Institute of Meteorology - INMET, located in the neighborhood of Curado, in the city of Recife-PE, were considered. This information was obtained from the digital platform of APAC (Agência Pernambucana de Águas e Clima).

According to the data generated by the selected pluviometric station, the monthly precipitation averages of the region studied were analyzed and it was found that the site has total average annual precipitation of 2,209.5 mm. The month of November with an average monthly precipitation of 37.14 mm presents the lowest average of the year, while the month of June presents itself as the month with the highest average precipitation with 419.50 mm. The rainy season in the city of Recife is from March to August, as shown in Figure 2.

Figure 2: Average monthly precipitation (2000 - 2020) in the study area



Source: Prepared by the authors from APAC data, 2022.

4.3 Determination of water demands

Because it is a shopping malls typology building, the estimate of the maximum number of users who frequented the building was evaluated based on the histories related to the flow of people provided by the mall. Thus, the estimate reached an average total of 1,569,017 people per month in the entire enterprise, for the years 2012 to 2021. Between 2020 and 2021 there was a reduction in the total monthly average, motivated by the Covid-19 pandemic, generating an impact on the total monthly average of the period studied. Thus, the daily total of users corresponds to 52,300 people.

The building's water consumption was evaluated based on a monthly monitoring, performed through readings in the building's water meter and through the analysis of consumption histories provided by the mall's administrative sector. The building has an average monthly water consumption equal to 20,059 m³, supplied only by the local utility company, in a historical series for the years 2012 to 2021. The use of other sources of supply (tank cars and wells) were discarded due to the lack of periodicity in the acquisition of tank cars and the exclusive use of wells for garden irrigation. The total daily consumption of the enterprise was 668.63 m³.

The garden area in the development is 17,771.00 m², thus, 35,542 L/day or 35.54 m³/day are necessary to supply the demand for garden irrigation, according to TOMAZ (2010). For the sizing of the rainwater reservoir, the extreme case of green area watering during 30 days a month was adopted, with a monthly demand of 1,066.26 m³ of water to be replaced by rainwater. A área de piso dos banheiros do empreendimento é de 1.033,94 m², deste modo, são necessários 2.067,88 L/dia ou 2,07 m³/dia, para suprir a demanda de água para lavagem do piso, conforme (TOMAZ, 2010).

The average volume for supplying the cooling center's water demand is 19,388.19 L/day or 19.39 m³/day.

The project has 179 toilets with an average consumption of 102.36 L/day per toilet bowl and 42 urinals with an average consumption of 31.04 L/day per urinal. The average water consumption values per toilet bowl and per urinal were obtained by monitoring the hydrometers of the model bathroom. Thus, 19,626.12 L/day or 19.63 m³/day are needed to supply the water demand for flushing the toilets and urinals.

The calculated monthly water demand for non-potable purposes resulted in a water consumption of 2,298.90 m³/month, which represents 11.46% of the total demand for potable water of the building. For the simulation and sizing of the reservoir it was considered that 12% of the potable water demand would be replaced by the use of rainwater, leaving a margin of 0.54% of water consumption for possible losses. The maximum daily non-potable water demand, i.e., on a day when garden watering, washing of bathroom floors, replacement of cooling tower water and flushing of toilets and urinals would be 76.63 m³/day. Table 1 presents a summary of the results obtained for the non-potable water demand of the building.

Table 1: Demand for non-potable water

Use	Daily demand (m³/day)	Frequency	Monthly demand (m³/month)
Garden irrigation	35,54	30 days/month	1.066,20
Floor washing	2,07	30 days/month	62,10
Cooling Tower	19,39	30 days/month	581,70
Toilet bowl and urinal flushing	19,63	30 days/month	588,90
Total non-potable water demand	**76,63**	**-**	**2.298,90**

Source: Prepared by the authors

4.4 Determination of the catchment área

Besides knowing the local rainfall to determine the volume of rainwater to be collected, it is also necessary to know the characteristics of the contribution area. From the analysis of the building's roof plan, it was found that the maximum rainwater catchment area is 52,149 m². For the simulation on Neptune computer program, the maximum catchment area was divided every 10,000 m² into five different catchment areas, ranging from 10,000 to 52,149 m², in order to verify if the whole catchment area, or only part of it, would be necessary to compose the system and supply the building's non-potable water demand, referring to 12% of the estimated monthly water consumption.

According to the simulations performed, whose results are presented in Table 2, it is evident that the maximum catchment area has the capacity to meet only 76.87% of the demand for non-potable water, considering the implementation of the 640,000 L lower reservoir. The potential for meeting the rainwater demand for the 52,149m² area is 32.44% higher in relation to the 10,000m² area, as well as 15.09%, 7.02% and 2.99% respectively, for the catchment areas of 20,000 m², 30,000 m² and 40,000 m².

Therefore, the potential for drinking water savings was estimated in relation to the water demands. In summary, the results of the sizing of the volume of the lower reservoir, the potential for drinking water savings and the daily rainwater demand for the different rainwater catchment areas are presented in Table 2.

Thus, the area totaling 52,149m² was defined as the system's catchment area, since it offers the closest potential for rainwater supply to fully meet the building's non-potable water demands.

Table 2: Potential drinking water savings results for different roof catchment areas

Catchment area (m²)	Maximum volume of the lower reservoir (L)	Rainwater demand completely satisfied (%)	Potential for Potable Water Savings (%)
10.000	640.000	44,43	6,14
20.000	640.000	61,78	7,91
30.000	640.000	69,85	8,72
40.000	640.000	73,88	9,14
52.149	640.000	76,87	9,47

Source: Prepared by the authors.

4.5 Dimensioning of the reservoirs

The capacity of the lower rainwater reservoir was calculated using the computer program Neptune. The flow coefficient adopted was 0.90 (90% utilization). In addition, it was adopted as catchment area for all simulations, the area defined in item 4.4 of this work, equal to 52,149 m², and as initial runoff disposal, the value of 2 L/m², as suggested by NBR 15,527 (ABNT, 2019) in the absence of data.

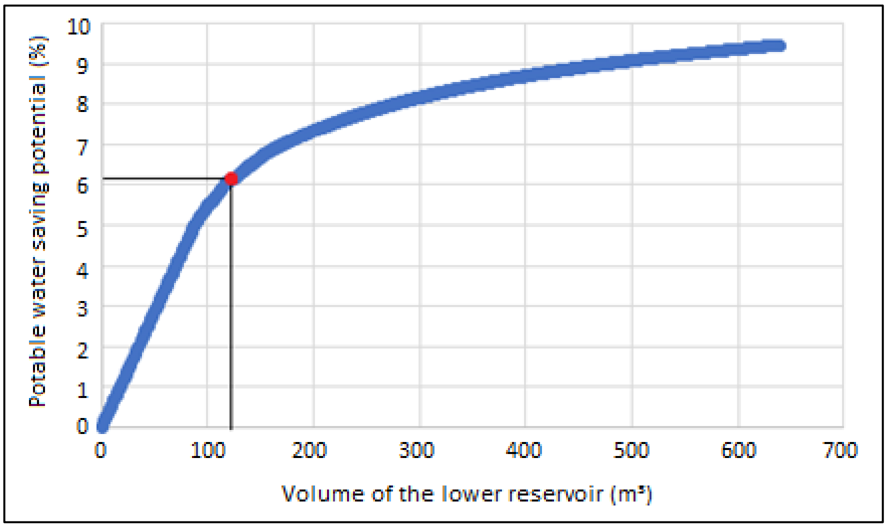
The simulation was performed for reservoirs with several volumes. The daily rainwater demand is 76,630 L. The simulations were initiated with a maximum volume of 640,000 L, due to the availability of an area around 320 m² on the land for the implantation of a reservoir of depth of 2 m.

The capacity of the upper rainwater reservoir is equivalent to the daily rainwater demand, knowing that for the withdrawal of rainwater from the lower reservoir to the upper reservoir, it was considered that first there will be withdrawal at the same time as rainwater consumption and then, if there is still rainwater demand, and if the lower reservoir is empty and the upper reservoir has water, there will be consumption without withdrawal. In this way, refilling will occur when the volume in the upper reservoir was equal to or less than 50% of the daily demand.

Volume variation was performed in 1,000 L intervals, and for each variation performed, a new potential for drinking water savings was verified until reaching the reservoir volume that promoted an increase equal to or less than 0.5% over the previous volume tested (MARINOSKI, 2007).

Os The results generated by the program indicated a volume for the lower reservoir equal to 117,000 L, with a potential of potable water savings of 6.02%. Still according to the generated results, the use of the maximum volume of 640,000 L would provide an increase in relation to the proposed volume of 3.44% in the potential savings, which would demand a larger investment for a reservoir of larger dimensions, with little increase in the potable water savings, as shown in figure 3.

Figure 3: Simulation for determining the volume of the lower reservoir



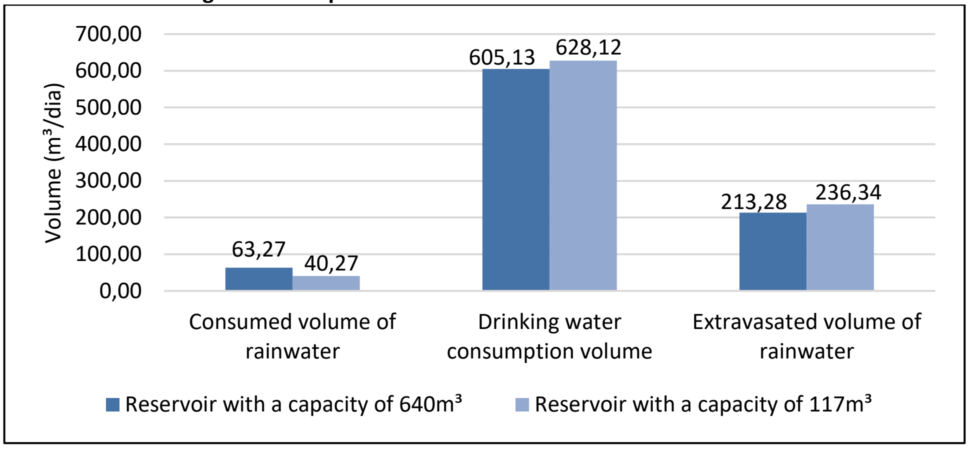
Source: Prepared by the authors

4.6 Analysis of drinking water consumption reduction

We verified a potential supply (complete and partial) of rainwater demand of 52.56% in the building studied for the simulation of the implementation of a lower reservoir with a capacity of 117,000 L and the supply (complete and partial) of rainwater demand of 82.56% for the simulation of the implementation of a reservoir with a maximum capacity of 640. 000 L, corresponding to water used for non-potable purposes, such as watering gardens, washing bathroom floors, flushing toilets and urinals, and supplying the central cooling plant, as shown in figure 4.

The objective of performing simulations is to obtain the appropriate reservoir volume for the rainwater harvesting system. Therefore, it is evident in figure 4 that the potable water savings suffer low variability in relation to the reservoir capacity. This is due to the stabilization of water supply and demand.

Figure 4: Comparison between 117m³ and 640m³ reservoirs



Source: Prepared by the authors

5 CONCLUSIONS

The present study, using the collected and estimated data, obtained the volume of the rainwater reservoir in order to partially supply the entire demand for non-potable water, generating the greatest potential for savings of potable water as possible.

The computational program Neptune was used, as it allows the sizing of the potential for potable water savings and the percentage of complete fulfillment of rainwater demand. In the building under study, all simulated roof areas were insufficient to meet water demands for non-potable use.

The maximum rainwater collection area of the development was assumed to be the total covered area, equivalent to 52,149 m², since the building facilities for rainwater collection and disposal are already provided for in the construction project, and because it provides an average of 76.87% complete service for the maximum reservoir proposed in the simulation.

The reservoir sizing performed in the Neptune computational program presented as 117 m³ the volume for the lower reservoir, which promoted an increase of just under 0.5% of potable water savings over the previous volume tested, generating a potential potable water savings of 6.02%.

The activity that causes the highest water consumption in the building corresponds to garden watering, consuming 46.38% of the total non-potable water demand, followed by toilet flushing and urinal flushing, which in turn consumes 25.62%.

After sizing the system, considering the potential savings in drinking water generated by the Neptune Computational Program equal to 6.02%, the monetary savings generated by the rainwater harvesting system would be R$11,556.27 per month or R$138,675.25 per year.

Therefore, it can be concluded that the potential for drinking water savings justifies the implementation of a rainwater harvesting system in a project of this size, proving to be technically feasible, given that it is effective in the use of rainwater, generating a considerable economic potential. The proposed upper and lower rainwater tanks can meet a significant percentage of the demand required for watering gardens, washing bathroom floors, flushing toilets and urinals, and supplying the central cooling system every day of the month, bringing future environmental and financial benefits. In addition, given the scarcity of water resources, especially considering the intensification of this problem in urban centers, such a system is of utmost importance, due to the range of possible applications for rainwater.

However, within the specific theme of this article, it is recommended for future studies that an economic analysis be carried out in order to evaluate the financial viability of implementing the system.

BIBLIOGRAPHICAL REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15527**: Aproveitamento de água de chuva de coberturas para fins não potáveis - Requisitos. Rio de Janeiro, 2019.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 10.844**: Instalações prediais de águas pluviais. Rio de Janeiro, 1989.

AGÊNCIA ESTADUAL DE REGULAMENTAÇÃO DE PERNAMBUCO (ARPE). *Resolução ARPE Nº 192/2021 - Publicada no DOE nº. 136 de 20/07/2021.* 2021. Disponível em: https://lojavirtual.compesa.com.br:8443/gsan/exibirConsultarEstruturaTarifariaPortalAction.do. Acesso em: 20 nov. 2022.

AGHAKOUCHAK, Amir; MIRCHI, Ali; MADANI, Kaveh; DI BALDASSARRE, Giuliano; NAZEMI, Ali; ALBORZI, Aneseh; ANJILELI, Hassan; AZARDERAKHSH, Marzi; CHIANG, Felicia; HASSANZADEH, Elmira *et al. 2021.* Anthropogenic drought: Definition, challenges, and opportunities. **Reviews of Geophysics**, v. 59, e2019RG000683. DOI: https://doi.org/10.1029/2019RG000683.

APAC – AGÊNCIA PERNAMBUCANA DE ÁGUAS E CLIMA. Disponível em: http://www.apac.pe.gov.br/meteorologia-/monitoramento-pluvio.php. Acesso em: 8 de setembro de 2022.

BINT, L.; GARNETT, A.; SIGGINS, A.; JAQUES, R.. Alternative water sources in New Zealand's commercial buildings. **Water Supply**, v. 19, n. 2, p. 371-381, 27 abr. 2018. IWA Publishing. DOI: http://dx.doi.org/10.2166/ws.2018.082.

BOCANEGRA-MARTÍNEZ, Andrea; PONCE-ORTEGA, José María; NÁPOLES-RIVERA, Fabricio; SERNA-GONZÁLEZ, Medardo; CASTRO-MONTOYA, Agustín Jaime; EL-HALWAGI, Mahmoud M.. Optimal design of rainwater collecting systems for domestic use into a residential development. **Resources, Conservation And Recycling**, v. 84, p. 44-56, mar. 2014. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.resconrec.2014.01.001.

GALVÃO, Ana; MARTINS, David; RODRIGUES, Andreia; MANSO, Maria; FERREIRA, Joana; SILVA, Cristina Matos. Green walls with recycled filling media to treat greywater. **Science Of The Total Environment**, v. 842, p. 156748, out. 2022. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.scitotenv.2022.156748.

GOIS, Eduardo H.B. de; RIOS, Carlos A.s.; COSTANZI, Ricardo N.. Evaluation of water conservation and reuse: a case study of a shopping mall in southern brazil. **Journal Of Cleaner Production**, v. 96, p. 263-271, jun. 2015. Elsevier BV. DOI: http://dx.doi.org/10.10-16/j.jclepro.2014.08.097.

GUZZO, Fernanda Ribeiro. **Estratégias para conservação de água potável através do aproveitamento de fontes não potáveis em uma edificação comercial de grande porte**. 2017. 151 f. Dissertação (Mestrado em Engenharia e Desenvolvimento Sustentável) - Universidade Federal do Espírito Santo, Vitória, 2017.

GHISI, E.; CORDOVA, M. M. Netuno 4. Programa computacional. Universidade Federal de Santa Catarina, Departamento de Engenharia Civil. Disponível em: http://www.labeee.ufsc.br/. 2014.

HASHIM, H.; HUDZORI, A.; YUSOP, Z.; HO, W.s.. Simulation based programming for optimization of large-scale rainwater harvesting system: malaysia case study. **Resources, Conservation And Recycling**, v. 80, p. 1-9, nov. 2013. Elsevier BV. DOI: http://dx.doi.org/-10.1016/j.resconrec.2013.05.001.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Malha Municipal.** 2021. Disponível em: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/15774malhas.html?=&t=dow-nloads. Acesso em 19 de outubro de 2022.

LEE, Khai Ern; MOKHTAR, Mazlin; HANAFIAH, Marlia Mohd; HALIM, Azhar Abdul; BADUSAH, Jamaludin. Rainwater harvesting as an alternative water resource in Malaysia: potential, policies and development. **Journal Of Cleaner Production**, v. 126, p. 218-222, jul. 2016. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.jclepro.2016.03.060.

LIU, Wenbin; SUN, Fubao; LIM, Wee Ho; ZHANG, Jie; WANG, Hong; SHIOGAMA, Hideo; ZHANG, Yuqing. Global drought and severe drought-affected populations in 1.5 and 2 °C warmer worlds. **Earth System Dynamics**, v. 9, n. 1, p. 267-283, 19 mar. 2018. Copernicus GmbH. DOI: http://dx.doi.org/10.5194/esd-9-267-2018.

MARINOSKI, A.K. **Aproveitamento de Água Pluvial para Fins Não Potáveis em Instituição de Ensino**: Estudo de Caso em Florianópolis – SC. Trabalho de Conclusão de Curso. Curso de Graduação em Engenharia Civil, Universidade Federal de Santa Catarina – UFSC, Florianópolis, 2007.

MORALES-PINZÓN, Tito; RIERADEVALL, Joan; GASOL, Carles M.; GABARRELL, Xavier. Modelling for economic cost and environmental analysis of rainwater harvesting systems. **Journal Of Cleaner Production**, v. 87, p. 613-626, jan. 2015. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.jclepro.2014.10.021.

NECHIFOR, Victor; WINNING, Matthew. Global Economic and Food Security Impacts of Demand-Driven Water Scarcity—Alternative Water Management Options for a Thirsty World. **Water**, [S.L.], v. 10, n. 10, p. 1442, 13 out. 2018. MDPI AG. DOI: http://dx.doi.org/10.3390/w10101442.

ONU - Organização das Nações Unidas. Population Division - **World Population Prospects 2022**. Disponível em: https://population.un.org/wpp/Download/Standard/Population/. Acesso em: 17 de jul. 2022.

PIMENTEL-RODRIGUES, Carla; SILVA-AFONSO, Armando. Rainwater Harvesting for Irrigation of Tennis Courts: a case study. **Water**, v. 14, n. 5, p. 752, 26 fev. 2022. MDPI AG. DOI: http://dx.doi.org/10.3390/w14050752.

PINTO, F. Silva; MARQUES, R. Cunha. Desalination projects economic feasibility: a standardization of cost determinants. **Renewable And Sustainable Energy Reviews**, v. 78, p. 904-915, out. 2017. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.rser.2017.05.024.

SAMPLE, David J.; LIU, Jia. Optimizing rainwater harvesting systems for the dual purposes of water supply and runoff capture. **Journal Of Cleaner Production**, v. 75, p. 174-194, jul. 2014. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.jclepro.2014.03.075.

SEPEHRI, Mehdi; MALEKINEZHAD, Hossein; ILDEROMI, Ali Reza; TALEBI, Ali; HOSSEINI, Seyed Zeynalabedin. Studying the effect of rain water harvesting from roof surfaces on runoff and household consumption reduction. **Sustainable Cities And Society**, [S.L.], v. 43, p. 317-324, nov. 2018. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.scs.2018.09.005.

SILVA, Alisson Caetano da; SILVA, Arícia Fernandes Alves da; SILVA, Simone Rosa da; SILVA, Marcela Tavares de Araújo. Análise de viabilidade técnica e econômica de um sistema de águas pluviais para fins não potáveis em uma instituição de ensino federal em Pernambuco. **Revista Gestão & Sustentabilidade Ambiental**, v. 8, n. 1, p. 78, 4 abr. 2019. Universidade do Sul de Santa Catarina - UNISUL. DOI: http://dx.doi.org/10.19177/rgsa.v8e120197-8-98.

SILVA JUNIOR, Marcos Antonio Barbosa da; SILVA, Simone Rosa da; ALCOFORADO, Roberta de Melo Guedes. Avaliação do sistema de microdrenagem visando à sustentabilidade de área urbana com problemas de alagamentos e influência das marés. **Revista Nacional de Gerenciamento de Cidades**, [S.L.], v. 4, n. 24, p. 01-17, 23 dez. 2016. ANAP - Associacao Amigos de Natureza de Alta Paulista. DOI: http://dx.doi.org/10.17271/2318847242420161320.

SOUSA, Vitor; SILVA, Cristina Matos; MEIRELES, Inês C.. Technical-financial evaluation of rainwater harvesting systems in commercial buildings–case ase studies from Sonae Sierra in Portugal and Brazil. **Environmental Science And Pollution Research**, [S.L.], v. 25, n. 20, p. 19283-19297, 10 nov. 2017. Springer Science and Business Media LLC. DOI: http://dx.doi.org/10.1007/s11356-017-0648-0.

TOMAZ, Plínio. Aproveitamento de água de chuva em áreas urbanas para fins não potáveis. 2010. Disponível em: https://909d9be6-f6f1-4d9c-8ac9-115276d6aa55.filesusr.com/ugd/0573a5_bfa504956e664155b22974ef016e05a7-.pdf?index=true. Acesso em: 13 set. 2022.

UNFRIED, Kerstin; KIS-KATOS, Krisztina; POSER, Tilman. Water scarcity and social conflict. **Journal Of Environmental Economics And Management**, v. 113, p. 102633, maio 2022. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.jeem.2022.102633.

VANEGAS-ESPINOSA, Luis Ignacio; VARGAS-DEL-RÍO, David; OCHOA-COVARRUBIAS, Gabriela; GRINDLAY, Alejandro Luis. Flood Mitigation in Urban Areas through Deep Aquifer Recharge: the case of the metropolitan area of guadalajara. **International Journal Of Environmental Research And Public Health**, v. 19, n. 6, p. 3160, 8 mar. 2022. MDPI AG. DOI: http://dx.doi.org/10.3390/ijerph19063160.

YANNOPOULOS, Stavros; GIANNOPOULOU, Ioanna; KAIAFA-SAROPOULOU, Mina. Investigation of the Current Situation and Prospects for the Development of Rainwater Harvesting as a Tool to Confront Water Scarcity Worldwide. **Water**, v. 11, n. 10, p. 2168, 18 out. 2019. MDPI AG. DOI: http://dx.doi.org/10.3390/w11102168.

WANG, XI; LI, Junqi; LI, Yingxia; SHEN, Zhenyao; WANG, Xuan; YANG, Zhifeng; LOU, Inchio. Is urban development an urban river killer? A case study of Yongding Diversion Channel in Beijing, China. **Journal Of Environmental Sciences**, [S.L.], v. 26, n. 6, p. 1232-1237, jun. 2014. Elsevier BV. DOI: http://dx.doi.org/10.1016/s1001-0742(13)60593-8.

ZHANG, Jian; ZHANG, Chunling; SHI, Wanli; FU, Yicheng. Quantitative evaluation and optimized utilization of water resources-water environment carrying capacity based on nature-based solutions. **Journal Of Hydrology**, v. 568, p. 96-107, jan. 2019. Elsevier BV. DOI: http://dx.doi.org/10.1016/j.jhydrol.2018.10.059.