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Regional Case Study

Optimising Flood Risk Reduction in Bali's Provincial Government Center through Cultural Philosophy Approach and GIS-based Conservation of Infiltration Wells

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Abstract

Bali's administrative center, Renon Village, faces an increased risk of flooding due to land cover change. Conservation is needed to reduce this risk by improving water infiltration capacity. Infiltration wells are a solution to increase infiltration capacity. The Tri Hita Karana concept approach, especially Palemahan, in Balinese culture is adopted to implement infiltration well conservation with the support of GIS technology and by flood regulations and infiltration wells. The analysis showed that with a land area of 100 m^2, the dimensions of the infiltration well were obtained in diameter of 1 m, and a depth of 2 m with a total of 2 pieces could absorb 2.46 m^3 of rainwater. The application of infiltration wells in the study area can reduce the discharge and volume of flood peaks of 2 years, 5 years, 10 years, 25 years, 50 years, 100 years, and 200-year flood peaks, effectively reducing from 8.61% to 31.24%. This research supports the planning of sustainable drainage with a Low Impact Development approach. In addition, the construction of infiltration wells also contributes to preserving water conservation and applying green buildings that are environmentally friendly and energy efficient.

Keywords: Infiltration wells; floods; tri hita karana; culture; regulation; geographic information systems.

1. Introduction

The administrative center of Bali Province is located in the Renon sub-district, South Denpasar District. As the center of government, this region is increasing rapidly in terms of development, economy, and socio-culture. South Denpasar, with an area of 49.89 km^2, occupies the first position with 39.60% of the total area of Denpasar City (BPS Kota Denpasar, 2023). Based on the results of the population projection of Denpasar City in 2022, South Denpasar's population amounted to 217,500 people, with a population growth rate in 2022 reaching 0.12% (BNPB, 2018). Population growth and density change the land cover from catchment to impermeable land, resulting in increased rain runoff volume and speed that can overwhelm drainage infrastructure. This makes urban areas always at risk of flooding when rain occurs. The relatively high population density will exacerbate the impact, especially the effect of infrastructure damage that results in material losses to city residents (Pariartha, 2019).

According to the Denpasar City BPBD, in 2021, flood events in Denpasar City reached 37 cases of flood events. The criteria for classifying flood-prone areas using population density data and rainfall data indicate that the South Denpasar region has the most significant potential among other Denpasar regions (Adisanjaya et al., 2021). Denpasar City area with a very high level of flood vulnerability is found in a small part of East Denpasar, part of West Denpasar and most of South Denpasar, with a total area of 7,107.08 ha (59%) (Komang et al., 2017). This is directly proportional to BNPB data related to the Flood Hazard

Map of Denpasar City, Bali Province (BNPB, 2018), where the percentage of flood-prone areas to the area of each region shows that Denpasar City has the highest number where 22.04% of its area is included in flood-prone areas. As one of the districts that is the center of government, South Denpasar District is the center of attention of the wider community. Therefore, South Denpasar District must be a model, especially in environmental management. This is a formulation of problems that must be solved to achieve goals, one of which is reducing flood risk in the central area of the Bali Provincial Government.

Bali is an area thick with cultural diversity. One of the philosophies of Balinese Culture recognizes the concept of Tri Hita Karana, which can be interpreted as the concept of harmonious and balanced relations between contents and containers. This harmony is divided into three, namely the harmonious relationship between humans and God (Parahyangan), the harmonious relationship between humans and humans (Pawongan), and the harmonious relationship between humans and the environment (Palemahan) (Idedhyana et al., 2021). The application of palemahan is also manifested in customary law. In principle, there are always positive and negative elements (*Rwa Bhinneda*) as a supporter of the magical power of the universe. So, to harmonize it, a set of rules is needed that regulates what can be done to balance nature (*bhuana agung* and *bhuana alit*) and should not be done to prevent catastrophe (*sengkala salampah*). Based on this, the meaning and understanding of environmental conservation efforts from the beginning when related to aspects of customary law, especially in Bali, can not only be based on the preservation of nature in a visible way (*sekala*) but also the preservation and balance of magical nature (*niskala*), one of which is the environmental management system in the conception of Tri Hita Karana (Suadnyana, 2021; Widyani and Juliawan, 2021).

At this point, the Palemahan concept can be used as a foundation to reduce flood risk in the center of the Bali Provincial Government, one of which is by conservation. The conservation method approach is related to existing regulations, mainly to achieve the objectives of the water resources management strategy in the Bali-Penida River Basin, which is included in the aspect of a series of water resources conservation activities (Balai Wilayah Sungai Bali-Penida, 2019). Reducing flood risk through water resources conservation is also one of the government's programs for implementing a Green Economy. In particular, a Green Economy is an economic view aiming to improve human welfare and social equality while significantly reducing environmental risks (Setiawan et al., 2020).

Green Economy in the form of environmental conservation is closely related to the concept of Palemahan in Tri Hita Karana, which is in the philosophy of Balinese Culture and is also a description of the form of implementation of several government regulations, including through the Regulation of the Minister of Environment Number 12 of 2009 and in the Regulation of the Mayor of Denpasar Number 18 of 2010 which describes the form of conservation of water resources related to the use of rainwater (Menteri Negara Lingkungan Hidup, 2009; Walikota Denpasar, 2010). The use of rainwater aims to reduce flood discharge, which can be done by increasing infiltration capacity in watersheds. Infiltration wells are an option that can be used to increase infiltration capacity in watersheds (Januriyadi et al., 2019).

In this era of increasingly developing technology, digitalization is the method that is widely used. Related to the analysis process of the application of infiltration wells, GIS (Geographic Information System) will be used, which is an information system designed to work with spatial data sources. GIS-based geographic data is commonly used in processing processes such as planning, implementation activities, slope mapping, and land use mapping (Upara, 2022). In addition, many disaster mitigation planning has also utilized GIS, one of which is related to flood disaster mitigation and mapping mitigation study plans (Angelina et al., 2022; Fatahillah et al., 2022; Muftiara et al., 2023; Widiasih et al., 2022). In this study, one of the types of data in the form of maps entered into the GIS is the Digital Elevation Model (DEM), which is essential if spatial data processing is carried out (Sadad and Ridlo, 2021). DEM data in this study plays a role in determining the watershed that affects the study area, namely South Denpasar. Watershed adjustment of a place is necessary for planning infiltration wells because when water overflows, it will go to the river flow with a lower elevation and enter one watershed. Watershed adjustments have also not been listed in SNI 03-2453-2002, which regulates procedures for planning rainwater infiltration wells for yard land (Badan Standardisasi Nasional, 2002). Referring to the background and technological developments, it is necessary to conduct research on the Cultural Philosophy Approach to Reducing Flood Risk in the Bali Provincial Government Center with Geographic Information System-Based Infiltration Well Conservation. This becomes a problem formulation that must be solved to achieve goals, one of which is to reduce the risk of flooding in the central government area of Bali Province, contribute to preserving water conservation and apply green buildings that are environmentally friendly and energy efficient.

2. Methods

The method used in this study is a quantitative descriptive analysis method. The analysis was conducted to calculate and describe the effectiveness of infiltration wells in reducing flood risk in the Bali Provincial Government Center located in Renon Village, South Denpasar District. The problem discussed in this study is an effort to support the conservation of water resources by reducing flood risk using the application of Geographic Information Systems in analyzing the effectiveness of infiltration wells. Furthermore, secondary data collection implementation methods are needed as the basis for GIS analysis from the Geospatial Information Agency web portal, hydrological analysis from the Bali-Penida River Basin Center, and data for soil classification analysis for infiltration well planning from soil type maps and primary data from soil investigation results and soil permeability test results in the laboratory.

Data analysis in this study begins with analysis using GIS-based applications to carry out the process of mapping watersheds and analyzing residential land cover supported by terrain data. Furthermore, conducting hydrological calculations for regional rain, frequency analysis, rainfall plans, and flood discharge calculations with runoff coefficient and soil permeability coefficient values based on soil type maps, soil permeability test data from laboratory tests, and groundwater level adjusted to SNI 2415-2016 (Yekti et al., 2021) and Denpasar Mayor Regulation Number 18 of 2010. The last step is to plan infiltration wells by the provisions of SNI 03-2453-2002, which regulate the planning of infiltration wells for yard land. This reflects the application of Tri Hita Karana's philosophy of harmony between humans and nature (Yekti, 2017).

The life of the Balinese people depends on preserving nature in terms of Hindu community activities, especially now that Bali depends on its energy source in the agricultural, natural, and cultural tourism sectors. Especially in Bali itself has traditions and cultures that develop along with the preservation of nature and culture. Some are sacred certain trees, Caru rituals, Nyepi, Ngusaba, Subak, etc. One form of ceremony that Hindus still maintain to maintain the success of the implementation of the Tri Hita Karana Concept in terms of maintaining Palemahan (environment) relations is the Tumpek Wariga ceremony. This ceremony is intended to harmonize the Balinese Hindu community's religious, social, and cultural life with the sustainability of the surrounding nature. Celebrating the holy day of Tumpek Wariga is an effort to care for and get closer to nature (Suseni, 2020).

2.1. Research Location

This study was conducted in a flood-prone area of Renon Village, which is included in the Ngenjung Watershed (Figure 1b). Ngenjung watershed has an area of 3.28 km^2 and 5.54 km for the length of the river. The type of river is perennial, meaning the basic flow comes from groundwater. In addition, the Ngenjung watershed was chosen because of its location in the central government area, so it is efficient to be a pilot location to introduce the application of infiltration wells to residents and a form of support in building sustainable green infrastructure.

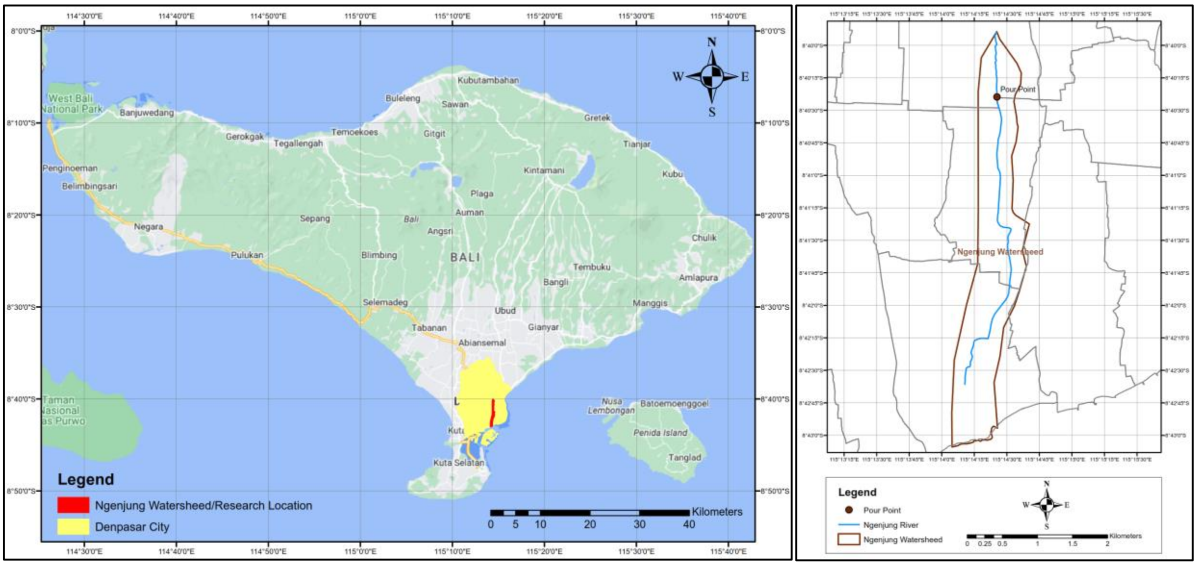


Figure 1a. Bali Island Figure 1b. Ngenjung Watersheed

Figure 1. Research location

2.2. Geographic Information System (GIS) analysis with remote sensing

Remote sensing can be defined as the science, art, and technique of obtaining information about an object without directly touching the observed object (Lembaga Penerbangan dan Antariksa Nasional, 2014). In the analysis, remote sensing is carried out to be the basis for dividing study areas and identifying land use through transportation model (DEM) processing using GIS software (Indarto, 2016). The steps required to create a river network and watershed boundary from DEM in ArcGIS software start from starting the direction of water flow with the flow direction algorithm, reducing the basin, and with the sink algorithm. Next, determine the selection of flow directions, sort the river order (stream to feature), connect the river network sections (stream link), select the flowselectsegment with the flow length algorithm, and snap the pour point. The last step is to define the watershed boundary.

2.3. Hydrological Analysis

The hydrological analysis is calculated based on rainfall data and the Ngenjung Watershed Map. This analysis has several steps that must be passed until we finally get data on rain and flood discharge plans. Analysis of regional rainfall calculations is based on the last ten years of maximum daily rainfall data from nearby rain stations. Next, the study of the plan's rainfall intensity with the Mononobe Method is calculated using equation (1) (Triatmodjo, 2008):

$$I_t = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \quad \text{.......(1)}$$

Information:
I = rain intensity (mm/hour)
R24 = Maximum daily rainfall in 24 hours (mm)
T = duration of rain (hour)

The calculation of runoff discharge is calculated using a practical rational method. This method can describe the relationship between runoff discharge and rainfall magnitude practically applicable to watershed areas up to 5,000 hectares (Badan Standardisasi Nasional, 2016). The two main components are concentration time (tc) and rainfall intensity (itc), described in Equation 5.

$$Q_p = 0.00278\, C.I.A \quad (2)$$

Information:
Qp = peak flood discharge (m^3/s)
C = runoff coefficient
I = rain intensity during concentration time (mm/hour)
A = watershed area (Ha)

$$C = 0.9\, l_m + (1 - l_m)\, C_p \quad (3)$$

$$lm = \frac{A\ waterproff}{A\ total} \quad (4)$$

Information:
C = runoff coefficient
Cp = run-off coefficient for non-impermeable areas
Lm = waterproof ratio

Approximate concentration time approach for flow in the field using Kirpich's formula (1940).

$$t_c = 0.0195\, L^{0.77} S^{-0.385} \quad (5)$$

Information:
tc = time in minutes
L = length of deep slopes (m)
S = slope from the slope (m/m).

2.4. Infiltration Well Analysis

Infiltration well analysis is planned in each sub-watershed of the study area, with the analysis results in the form of discharge and flood volume that infiltration wells can reduce. Infiltration wells are meant to collect and absorb rainwater into the ground, which can prevent land subsidence, minimize the spread of seawater infiltration/intrusion toward land, and increase groundwater potential (Duppa, 2017). In this study, the analysis was adjusted to the procedures for planning rainwater infiltration wells for yard land as stated in SNI 03-2453 as follows (Badan Standardisasi Nasional, 2002):
The volume of flood share is calculated by equation 6:

$$V_{ab} = 0.855.\, C_{container}.\, A_{container}.\, R \quad (6)$$

Information:
Vab = volume of flood share to be accommodated by infiltration wells (m^3)
$C_{container}$ = runoff coefficient from the catchment plane (without units)
$A_{container}$ = container area (m^2)
R = average daily rain height (L/m^2/hari)

The volume of pervasive rain is calculated by equation (7) :

$$V_{rsp} = \frac{t_e}{R}.\, A_{total}.\, K \quad (7)$$

Information:
Vrsp = pervasive volume of rainwater (m^3)
te = effective rain duration (hour) = 0.9 x $R^{0.92}$ /60 (hour)
R = average daily rain height (L/m^2/day)
Atotal = well wall area + well bed area (m^2)
K = soil permeability coefficient (m/day)

Determining the number of rainwater infiltration wells, first calculating Htotal with equation (8) and continuing to equation (9):

$$H_{total} = \frac{V_{ab} - V_{rsp}}{A_h} \quad (8)$$

$$n = \frac{H_{total}}{H_{rencana}} \quad (9)$$

Information:
n = number of rainwater infiltration wells (units)
Htotal = total depth of rainwater infiltration wells (m)
Hrencana = planned depth < groundwater depth (m)

Infiltration discharge is the amount of water volume that can seep into the ground through infiltration wells every unit of time. Analysis of infiltration discharge is necessary to calculate the effectiveness rate of discharge absorption. Equation 10 is used to calculate the infiltration discharge with the primary condition that the infiltration well is flat and the ground surface is impermeable to water (Suripin, 2004) in (Rina et al., 2018)

$$Q_o = 4.R.K.H \quad (10)$$

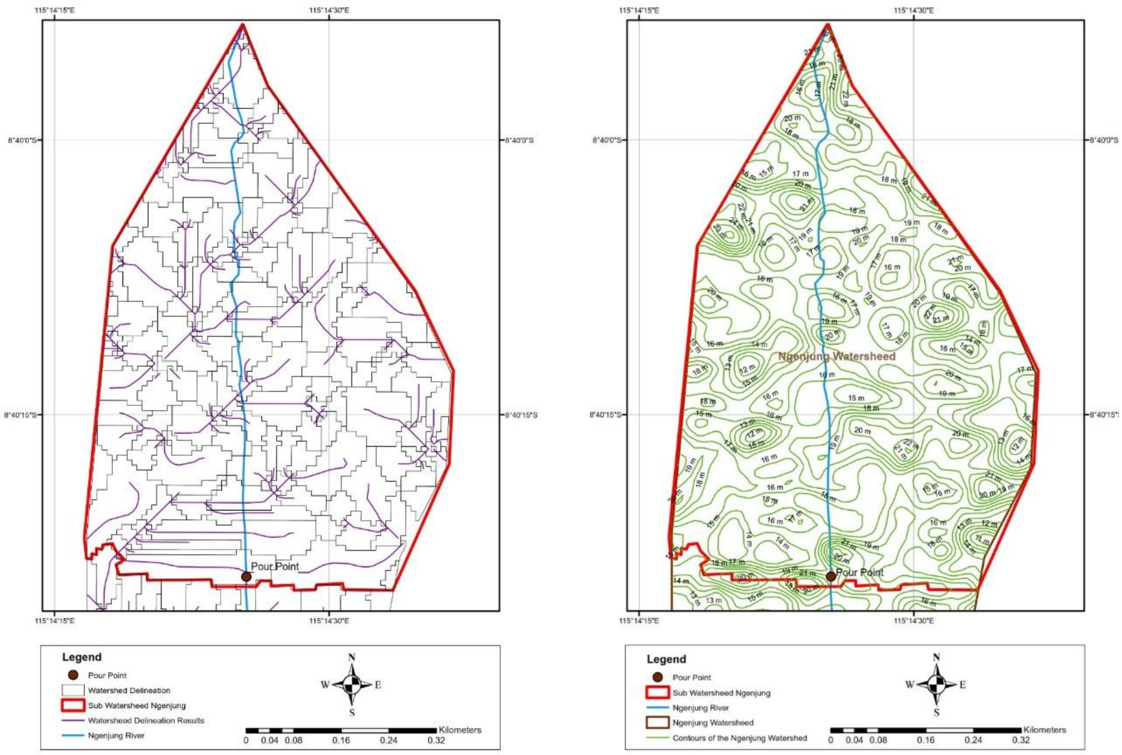
Information:
Qo = inlet water discharge (m^3/s)
R = radius of infiltration wells (m)
K = soil permeability coefficient (m/s); and
H = water level in the well (m)

In the analysis of infiltration wells described above, two parameters have not been determined in SNI 03-2453-2002: runoff coefficient and hydraulic conductivity. To determine the runoff coefficient of the catchment field, it will be adjusted based on the runoff coefficient and the percentage of waterproofness in the calculation procedure for planned flood discharge according to SNI No: 2415 (Badan Standardisasi Nasional, 2016). Meanwhile, the determination of hydraulic conductivity will be adjusted to the results of soil investigation tests at the study site and permeability checks in the laboratory.

3. Result and Discussion

3.1. Mapping analysis

The results of the first mapping analysis are related to the determination of the location of the study, namely the Ngenjung watershed area to the review point (from now on referred to as the "pour point") which often floods. This analysis is the result of the DEM-based delineation process of the Ngenjung Watershed so that later it can produce the Ngejung Sub Watershed (Figure 2a) and the contours in the Ngenjung Sub Watershed (Figure 2b) which become a reference in the subsequent analysis.



Sub watersheed ngenjung Contour sub watersheed ngenjung

Figure 2. Ngenjung watershed delineation results

Based on the results of watershed delineation analysis, the sub-watershed area of the study location was obtained at 0.3945 km2 with a river length of 0.94 km and elevation from upstream to pour point 0.0011. Furthermore, the mapping process carried out is land cover analysis based on satellite imagery maps, as shown in Figure 3.

Figure 3. Results of land cover analysis

The mapping analysis results (Figure 3) explain the effects of land cover area data in the entire Ngenjung Sub Watershed as a reference for calculating the drainage coefficient (C) and the area in infiltration well planning. In contrast, the area results are described in Table 1.

Table 1. Land cover area of Ngenjung Sub Watershed

Types of Land Cover	Broad (m^2)
Built-up land and places of activity - Built-up land (272,040 m2) - Places of activity (103,487 m2)	375,527
City Park	1,047
Fields	15,874
Total	**392,448**

3.2. Hydrological analysis

The result of the first hydrological analysis carried out was to classify the maximum daily rainfall based on the last ten years of rain data from the nearest rain post, namely the Buagan rain post, which is 4.9 km from the study location (Table 2). The following analysis is the calculation of plan rain, which begins with selecting distribution methods (Table 3) and then calculates the rain plan using the preferred distribution method, namely the Log Person III method (Table 4).

Table 2. Buagan Station monthly maximum rainfall data

YEAR	JAN	FEB	MAR	APR	MEI	JUN	JUL	AGT	SEP	OKT	NOP	DES
2012	49.0	67.0	40.0	87.0	75.0	27.0	24.0	3.0	2.0	34.0	42.0	97.0
2013	71.0	78.0	53.0	0.0	22.0	0.0	58.0	2.0	4.5	8.6	17.4	35.9
2014	97.0	41.0	45.0	18.0	52.0	92.0	53.0	3.0	4.0	7.0	32.0	98.0
2015	38.0	41.0	67.0	34.0	18.0	15.0	29.0	8.0	0.0	2.0	30.0	80.0
2016	39.0	59.5	63.5	26.5	33.0	2.5	5.5	1.0	0.0	0.0	25.3	82.5
2017	38.0	94.0	47.5	14.0	15.5	48.0	40.5	11.5	86.5	27.0	137.5	78.5
2018	65.0	177.0	81.0	49.0	15.0	62.0	24.0	2.0	6.5	81.0	61.0	87.0
2019	83.0	95.5	76.0	0.0	5.5	75.0	9.0	68.0	45.0	13.5	91.0	69.0
2020	96.5	28.5	53.0	18.0	10.5	0.0	2.5	1.0	1.0	0.0	29.0	57.0
2021	76.0	75.0	37.5	18.5	29.0	28.0	14.0	14.0	14.0	58.5	27.0	49.0

Table 3. Selection of distribution type rain analysis plan

No	Types of Distribution	Condition	Calculation Results	Information
1	Normal Method	Cs = 0	Cs = 1.82	Not Approaching
		Ck = 3	Ck = 3.05	
2	Normal Log Method	$Cs = Cv^3 + 3Cv$ $Ck = Cv^8 + Cv^6 + Cv^4 + Cv^2 + 3$	Cs = 1.82 Ck = 3.05	Not Approaching
3	Gumbel Method	Cs = 1,14 Ck = 5,4	Cs = 1.82 Ck = 3.05	Not Approaching
4	Log Pearson III Method	In addition to the above values	Cs = 1.82 Ck = 3.05	Approach

Table 4. Precipitation Plan Log Person III Method

T (year)	P (%)	K_t	Y_t	R_t (mm)
2	50.0	-0.231	1.965	92
5	80.0	0.699	2.073	118
10	90.0	1.335	2.146	141
25	96.0	1.397	2.156	143
50	98.0	2.713	2.309	204
100	99.0	3.282	2.376	238
200	99.5	3.844	2.442	276

As shown in Table 4, the analyzed rainfall plan will be used to calculate infiltration well planning referring to SNI 03-2453-2002 and flood discharge referring to SNI 2415 2016. Furthermore, based on the results of DEM analysis and determination of flood study points, as shown in Figure 2, the concentration-time (tc) is calculated with the length of the river to the location point of 0.94 km and the elevation from upstream to the pour point of 0.0011. Using equation 5, obtained a concentration time of 52.97 minutes. Concentration time is a reference in determining rainfall intensity, which is then combined with runoff coefficients based on land cover and watershed area using equation 3 so that flood discharge can be repeated as in Table 5.

Table 5. Results of flood discharge analysis

Flood Discharge	Runoff coefficient (C)	Intensity-based on tc (I)	Catchment area (A)	Peak flood discharge (Qp)
2-year return period	0.883	34.794	39.245	3.351
5-year return period	0.883	44.696	39.245	4.305
10-year return period	0.883	53.020	39.245	5.106
25-year return period	0.883	53.898	39.245	5.191
50-year return period	0.883	76.821	39.245	7.399
100-year return period	0.883	89.548	39.245	8.624
200-year return period	0.883	104.165	39.245	10.032

Based on the results of the peak flood discharge analysis in Table 5, the return period flood discharge for 2 years is 3.351 m^3/second, 5 years is 4.305 m^3/second, 10 years is 5.106 m^3/second, 25 years is 5.191 m^3/second, 50 years is 7.399 m^3/second, 100 years is 8.624 m^3/second, and the return period of 200 years is 10.032 m^3/second. This discharge will be the primary data in subsequent analysis by measuring the discharge release volume decrease.

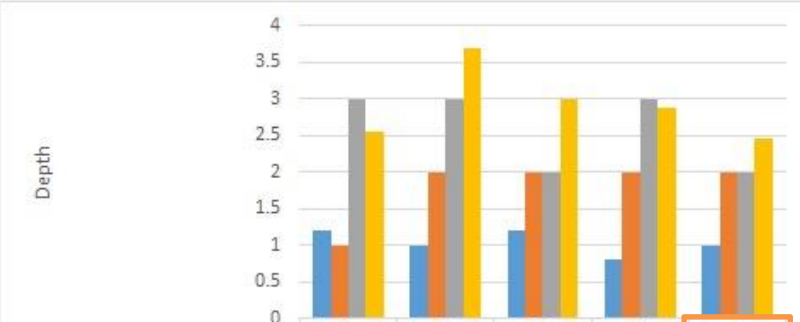
3.3. Infiltration well analysis

Infiltration well analysis has calculation parameters. Apart from the mapping and hydrological analysis results, some parameters must be determined initially, namely the value of water permeability. In this study, the results of permeability analysis by testing three soil samples in the laboratory at a depth of 2 meters obtained a permeability coefficient of 0.004 cm/s or 14.28 cm/hour with detailed calculations as in Table 6, which when adjusted to SNI permeability can be classified relatively fast soil permeability which is included in the technical requirements for the construction of infiltration wells.

Table 6. Permeability test results

Information	Unit	Drill		
		Depth (m)		
		2	2	2
Soil sample area f = 5,1 cm, A	cm^2	20.43	20.43	20.43
Soil sample height L	cm	15.00	15.00	15.00
The difference in water height and soil sample h	cm	59.00	59.00	59.00
Time t	s	180.00	240.00	300.00
Water volume in time t, Q	ml	57.00	77.00	96.00
Permeability, k = (Q.L)/ (A.h.t)	cm/sec	0.004	0.004	0.004
Water temperature in the burette	°C	29.00	29.00	29.00
Temperature correction		0.999	0.999	0.999
k, after correction	cm/sec	0.004	0.004	0.004
Average Permeability Coefficient k	cm/sec	0.004		
	cm/hour	14.28		

The following analysis is the analysis of infiltration wells by SNI 03-2453-2002 with parameter values that have been analyzed previously and based on the results of the investigation of the depth of the Groundwater Table of the study area, and it was obtained >1.5 m – 2.5 m, this is following the technical requirements of infiltration wells (Badan Standardisasi Nasional, 2002; Yekti et al., 2021). In addition to the Groundwater Level, the determination of the dimensions of urban infiltration wells is adjusted to the regulations on the provision and utilization of green open space as explained in the regulation of the Minister of Agrarian Affairs and Spatial Planning (Peraturan Menteri Agraria dan Tata Ruang, 2022) states that there must be at least 10% Green Open Space on built-up land/private land. The following results compare the dimensions and number of infiltration wells based on SNI recommendations with 100% performance efficiency, as shown in Figure 4.



	1	2	3	4	5
Diameter (m)	1.2	1	1.2	0.8	1
Depth (m)	1	2	2	2	2
Number of Infiltration Wells	3	3	2	3	2
Vrsp (m3)	2.55	3.69	3	2.88	2.46

Figure 4. Results of the analysis of circle cross-sectional infiltration wells

Based on the results of Figure 4, which is then adjusted to the technical requirements for the layout of infiltration well construction, groundwater level height, regulations on the availability of Green Open Space, and SNI recommendations. So, the effective cross-section chosen is the 5th part of the circle cross-section, which is 1 m in diameter and 2 m deep, and with a total of 2 infiltration wells, can absorb 2.46 m^3 of collected rainwater. The construction of infiltration wells is planned to be applied to built-up land with an area of 272,040 m^2. If simplified, for the entire scope of land built in the sub-catchment, 5,440 infiltration wells are needed. The following are the results of calculating the effectiveness of infiltration wells in reducing flooding at a 5-year return period (Table 7 and Table 8) when applied to the entire Ngenjung sub-watershed area.

Table 7. The effectiveness of infiltration wells in reducing flood discharge over a 5-year return period

Description	Result
Water discharge into each infiltration well (Equation 10)	0.000159 m^3/sec
Total discharge into infiltration wells (number of built-up land infiltration wells x calculation result 1)	0.863 m^3/sec
Calculation of % effectiveness of the well (calculation results of 2 /5 year return period flood discharge)	20.06 %

Table 8. Effectiveness of infiltration wells in reducing flood volume over a 5-year return period

Description	Result
Calculation of the volume of water that can be accommodated by infiltration wells (V infiltration wells x total number of wells)	8,545 m^3
Calculation of flood share volume (Equation 6)	35,143 m^3
Calculation % of good effectiveness (Calculation result 1 / Calculation result	24.32 %

Based on the results of the calculation analysis in Table 7 and Table 8 above, it can be seen that the construction of infiltration wells at the study location can reduce flood discharge at the 5-year return period with an effectiveness of 20.06% and reduce flood volume with an effectiveness of 24.32%. Similar results were also found in previous research in Cirebon housing. 1 infiltration well could reduce runoff discharge by 9.47% for a 5-year return period (Mulyono et al., 2021) in the Citra Persada housing complex in West Lombok with a flood discharge of 0.479 m^3/second. After the absorption well was built, it decreased to 0.057 m^3/second (Yasa et al., 2020), and planning for infiltration wells in West Denpasar, which can reduce flood discharge by more than 50% (Pamungkas et al., 2023, 2022). Based on the same calculation steps, the results are shown below in Table 9 to see the effectiveness of each flood discharge period.

Table 9. Results of analysis of the level of effectiveness of infiltration wells in reducing flood discharge and flood volume

Description	Flood discharge (m^3/s)	Flood volume (m^3)	Infiltration well discharge (m^3/s)	Infiltration well volume (m^3)	Decrease in flood discharge	Decrease in flood volume
2-year return period	0.883	34.794	0.863	8,545	25.77%	31.24%
5-year return period	0.883	44.696	0.863	8,545	20.06%	24.32%
10-year return period	0.883	53.020	0.863	8,545	16.91%	20.50%
25-year return period	0.883	53.898	0.863	8,545	16.63%	20.16%
50-year return period	0.883	76.821	0.863	8,545	11.67%	14.15%

Description	Flood discharge (m^3/s)	Flood volume (m^3)	Infiltration well discharge (m^3/s)	Infiltration well volume (m^3)	Decrease in flood discharge	Decrease in flood volume
100-year return period	0.883	89.548	0.863	8,545	10.01%	12.14%
200-year return period	0.883	104.165	0.863	8,545	8.61%	10.43%

Based on the results of the calculation analysis in Table 9 above, it can be seen that the construction of infiltration wells at the study site can reduce flood discharge and volume with varying reduction effectiveness from 8.61% to 31.24%, according to the release when the flood recurs that occur. In terms of flood management, in addition to infiltration wells, there are also several methods to deal with this problem, such as normalization of rivers and channels or repair and expansion of channels, normalization of rivers, and harvesting rainwater (Bahunta and Waspodo,2019). Previous research explained that river normalization can only reduce flooding by a small part and requires a reasonably high time and budget (Deby, 2019). In this study, the analytical approach is micro-scale because it is based on several studies that state that the application of infiltration wells must be sustainable with urban drainage systems. The application of infiltration wells is an environmentally sound drainage concept, "Low Impact Development" (LID), with an effort to maintain natural and hydrological conditions, such as initial conditions, before construction is carried out (Anwar, 2019; Joleha et al., 2023; Yunianta et al., 2022).

From this explanation, it can be concluded that infiltration wells can be an alternative method for reducing flooding in the Ngenjung sub-watershed, which is in urban areas with limited land. In addition, previous research explained that this alternative method can handle the occurrence of inundation in regions with lower elevations and can be accepted by the general public (Bahunta and Waspodo, 2019). The infiltration well method is also an effort to maintain water resource conservation and can create sustainability for water management (Hendri et al., 2022; Nurkhotimah et al., 2023) and can fulfill aspects of implementing green building management in terms of energy saving and environmentally friendly concepts (Karimah and Mokhtar, 2021; Kogege et al., 2023; Mandani et al., 2023).

Furthermore, to effectively reduce the risk of flooding, it is necessary to conduct careful research. Analysis of various factors such as geography, climate, urban spatial planning, and community needs is needed to determine the scenario that best suits local conditions. The results of this study can be a valuable guide for relevant agencies in managing flood risk. By implementing appropriate water conservation measures and based on sound scientific evidence, we can be more effective in dealing with the challenges of flooding that often harm people and the environment. In addition to the development of careful research, it is also necessary to take realization actions on the application of infiltration wells, especially in the lives of Balinese people who still maintain traditions and customary law, one of which is the implementation of the Tri Hita Karana Concept in terms of maintaining Palemahan (environmental) relationships by disliking or cleaning which is a Balinese culture that Balinese ancestors have inherited. There is a spirit or spirit of service and mutual assistance in rehearsing activities. The culture of Mereresik is supported by traditional ceremonies in Bali that are continuous and carried out regularly.

4. Conclusions

Analysis of infiltration well planning obtained results from the study area based on a Geographic Information System (GIS), namely in the form of the Ngenjung sub-watershed, which has the effectiveness of reducing discharge and peak flood volume at return periods of 2 years, 5 years, 10 years, 25 years, 50 years, 100 years, and 200 year return period with decreasing effectiveness varying from 8.61% to 31.24%. So, to reduce floods optimally in the Renon sub-district in a sustainable manner, this research can be used as a reference to a basis for planning an environmentally sound drainage concept with Low Impact Development. In addition, the construction of infiltration wells also plays a role as a form of effort to maintain the conservation of water resources and the application of green buildings that are energy efficient and environmentally friendly.

The approach of environmentally friendly cultural philosophy and the implementation of regulations are short factors for the implementation of infiltration wells, especially in pilot areas, especially the center of government of Bali. As described earlier, applying rainwater harvesting systems based on infiltration wells certainly has many benefits. However, there has been no study on mapping the placement of infiltration wells in this study. Therefore, it is expected that in the following research, there will be an analysis related to a more comprehensive study of infiltration well modeling in smaller areas to produce an exact figure of the number of infiltration wells that can be built and can be analyzed more deeply about the level of effectiveness measured based on the placement of infiltration wells and additional analysis of the benefits of the contribution of infiltration wells to groundwater So that the value of the effectiveness level of infiltration wells is more optimal for its usefulness.

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