Comparative Analysis of Typical and Sustainable Drainage System to Floods Control in the Andean Mountain Range

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Abstract*— Every construction project should have a drainage system so that it works correctly with a projection to future decades. The main function of sustainable drainage systems is to reduce the flow resulting from heavy rains, in addition to minimizing costs and having a wide and free landscape. To find the solution to this problem, it is proposed to make a comparison between a sustainable drainage system and a typical system, having as a structure the management of water produced by rainfall in order to mitigate flooding. Likewise, information acquired from the SENAMHIInstitutional page was used, such as rainfall and temperatures, with which evapotranspiration and runoff were determined, whichwas taken as the most critical, to find the most critical flow of 0.002m3/s. These values were found with their respective formulas. Finally, once the most critical flow was obtained, it was proposed in the hydraulic modeling with a green ditch and a traditional ditch in the HEC-RAS software, with positive results for both designs. However, the design with a green ditch showed a slightly greater difference, evidencing that this proposal is more viable. In addition, its implementation is economical and eco-friendly for theenvironment.

***Keywords*— Sustainable urban drainage, green ditch, hydraulic modelling, HEC-RAS, flow, precipitation**

Resumen* – Cualquier proyecto de construcción civil debería de contar con un sistema de drenaje para que funcione positivamente con proyección a décadas futuras. Los sistemas de drenaje sostenibles tienen como función principal disminuir el caudal producto de las fuertes lluvias, además de minimizar costos y tener un paisaje amplio y libre. Para encontrar la solución a este problema se propone realizar una comparación entre un sistema de drenaje sostenible y un sistema típico, teniendo como estructura la gestión de aguas producidas por las precipitaciones para poder mitigar las inundaciones. Asimismo, se utilizó información adquirida de la página Institucional de SENAMHI como precipitaciones y temperaturas, con las cuales se determinó la evapotranspiración y la escorrentía,la cual se tomó a la más crítica, para hallar el caudal más crítico de 0.002 m3/s. Estos valores fueron hallados con sus respectivas fórmulas. Por último, una vez obtenido el caudal más crítico se planteó en el modelamiento hidráulico con cuneta verde y cunetatradicional en el software HEC-RAS teniendo como resultados positivos para ambos diseños. Sin embargo, el diseño con cuneta verde demostró una mínima diferencia mayor evidenciando que esta propuesta es más viable. Además, su implementación es económica y ecoamigable para el entorno.

***Palabras claves*—Drenaje urbano sostenible, cuneta verde, modelamiento hidráulico, HEC-RAS, caudal, precipitación**

I. INTRODUCTION

The urban drainage system is defined as the management of accumulated rain in a given region in order to divert water from one point to another [1]. An appropriate management of the natural water cycle is needed in order to avoid potential flood problems. Urban flooding is the product of natural phenomena or alterations such as heavy rains, land subsidence, etc. Regarding the latter, structural flood risk controls are implemented for the protectionof cities (avenues, streets, etc.), as the installation of ditches, in order to collect and transport the water and, thus, prevent flooding. A case presented is mentioned in local reports, media from the city of Jaén, which reported that on March 14, 2022 there was excessive rainfall which caused the Avenida Manuel Antonio Mesones Muro to be completely flooded, which generated material losses and difficulty in transporting smaller vehicles. For a type of traditional system on roads, [2] mentions that the function of this is to remove all the water from said roads. There are types of ditches on roads: surface ditch, subsurface drainage systems, slope drainage ditch, gutter system. The most common because it is less expensive is the surface ditch, which consists of shallow excavations parallel to the tracks.

However, its structural efficiency reduces when their level of capacity is exceeded due to anomalous weather phenomena with high rain duration events triggering the increasing of the drainage areas. Thus, the current traditional drainage system is insufficient. From the above, in order to overcome the problems related to traditional urban drainage. Currently, countries and cities are increasingly recognizingthe value of adopting Sustainable Stormwater Management goals and measures [3]. Likewise, it mentions that green ditches can be defined as cavities designed in the form of channels which are covered with grass and with ideal slopes of "< 1V:3H". Its objective is to store, capture, conduct, and reduce the volume and velocity of the runoff peak flow, which is collected from nearby impervious surfaces. [4]. The inclusion of green ditches at the ends or in the center of the roads is an example of an sustainable drainage solution.

Including green ditches permits the collection of rainwater that is concentrated on high slopes []. The concentrated or collected water is divided into the entire green area of the study area. With this traditional ditch, a well is required every 100m, while in the wet green ditch it has greater absorption, has a higher Manning number, and therefore fewer wells must be placed, and this generates less costs.

According to these definitions, a comparison study was carried out. This study reports the comparison between the green ditch with respect to the traditional ditch to see the benefit that each of these presents in a situation of pluvial flooding in Cajamarca region located in the Peruvian Andean Mountain range.

II. Materials and Methods

The information on rainfall was collected from the most critical month of the year from the SENAMHI Institutional page, including the maximum and minimum temperature, from the city of Jaén (Cajamarca) and the data taken was from March 1 to 31, 2022. Next, before calculating evapotranspiration and water balance, the bar chart was presented as a summary of the pluvial precipitation data presented in figure 1.

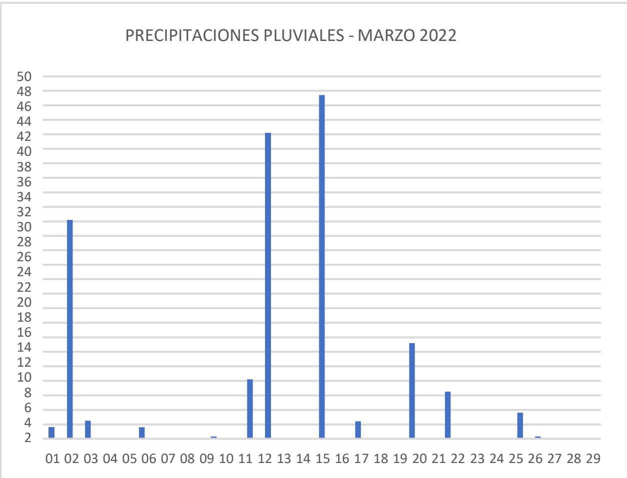

Fig. 1. Graph of the pluvial precipitations of March 2022

For the water balance, the general equation (1) was used based on the precipitation data collected from SENAMHI in order to obtain the daily runoff (m3/s).

$$PP = E + ETP + DELTA\ S \quad (1)$$

Where

PP = rain precipitation.
E = surface runoff
ETP = evapotranspiration
DELTA S = change in storage (soil or rock)

In order to find the evapotranspiration, the search for minimum, maximum, average temperature, relative humidity is carried out and with all the mentioned data the water balance is estimated. Likewise, with the runoff, length and width, the flow for the design is found (2) y (3).

$$ET0 = 0.0135\ (tmed + 17.78)\ Rs \quad (2)$$

ET0 = daily potential evapotranspiration, mm/day
Tmed= mean temperatura
Rs= incident solar radiation, converted to mm/day

$$Rs = R0 * KT * (tmax - tmin)\ 0.5 \quad (3)$$

R0= extraterrestrial solar radiation
Kt= coefficient
tmax = maximum daily temperature
tmin = minimum daily temperature

Likewise, the hec-ras software calculates the value of the manning coefficient through the following formula.

$$V = \frac{1}{n} . R^{2/3} . S^{1/2} \quad (4)$$

V = Runoff velocity in mt/sec
n = roughness coefficient
R = Hydraulic radius in meters
S = hydraulic conduit descent

After obtaining information on rainfall, the indicated formulas were applied to obtain the necessary values for the investigation, which were inserted into HECRAS software.

The selected study area is the Avenida Manuel Antonio Mesones in Jaen- Cajamarca. The section has 2.54 km and was divided into a wide route and a thin one. Likewise, two trapezoidal- shaped green ditches designs were proposed, the first of these having dimensions of 2.3 m at the upper base, 1.3 m at the lower base and 1 m in height for the wide route; and in the second design for the thin path, dimensions of 1 m for the upper base, 0.4 m for the lower base and 0.6 m in height. The green ditch uses a Manning coefficient of 0.03.

On the other hand, for the traditional ditch, two trapezoidal designs are proposed, the first of these having dimensions of 1.10m for the upper base, 0.90m for the lower base and 0.70m in height for the wide path; and in the second design for the thin path, dimensions of 0.50m of upper base, 0.3m of lower base and 0.20m of height. The traditional ditch uses a Manning coefficient of 0.02.

For both cases, the most critical flow was applied to determine the comparative analysis of the drainage system, which serves to observe which is the best absorption method and thus be able to avoid pluvial floods that generate material and/or human losses in the area. study. Then, in order to avoid floods that generate material and/or human losses in the study area,

III. Results and Analysis

Using the information acquired from the study area, the corresponding hydraulic modeling was applied for the design with green ditch and traditional ditch.
The input parameters for this modeling include:

•Critical flow
•Length of sections
•Elevation
•Manning coefficient
•Sizing of ditches

• Track width

Once the modeling is done in HEC-RAS with the input parameters, the results of "Flow Area", "WS Elev" and "Vel Chnl" are obtained. Thus, the results of the design with green ditch and traditional ditch will be presented in Table 1.

The results obtained in Table 1 show the values of "WS elev (m)", evidencing that the maximum difference between both hydraulic modeling is 0.41 (41%) and the minimum is 0.06 (6%). Likewise, it was determined that the values of "Vel Chnl (m/s)" present a maximum difference of 0.08 (8%) and a minimum difference of 0.00 (0%). Also, the values of "Flow Area (m2)" were obtained, with respect to said hydraulic modeling, which present a maximum difference of 14.39 and a minimum difference of -0.01 (-1%).

	Cuneta Tradicional			Cuneta Verde		
River Sta	W.S.Elevación (m)	Vel Chnl (m/s)	Flow Area (m2)	W.S.Elevación(m)	Vel Chnl (m/s)	Flow Area (m2)
2540	92.81		0.01	92.87		0.01
2440	89.81		0.01	89.87		0.01
2250	71.81		0.01	71.87		0.01
2125	63.81		0.01	63.87		0.01
2000	57.81		0.01	57.87		0.01
1875	47.81		0.01	47.87		0.01
1750	47.82	0	26.66	47.87	0	28.9
1640	47.82	0	36.06	47.87	0	38.9
1500	47.81		0.01	47.87		0.01
1375	43.81		0.01	43.87		0.01
1250	37.81		0.01	37.87		0.01
1125	31.81		0.01	31.87		0.01
1000	22.81		0.01	22.87		0.01
875	18.81		0.01	18.87		0.01
750	15.81		0.01	15.87		0.01
597	9.31	0.31	0.01	9.72	0.39	0
500	4.31	0.3	0.01	4.72	0.35	0.01
375	0.31	0.31	0.01	0.72	0.39	0
250	-0.69	0	12.04	-0.27	0	26.42
152	-0.69	0	48.44	-0.27	0	62.83
0	-0.69	0.31	0.01	-0.28	0.39	0

Tab. 1. Comparison of variables for traditional and green ditch

Then, the representation of a part of the section of the hydraulic modeling will be presented, through the HEC-RAS software, of the green ditch in Figure 2 and of the traditional ditch in Figure 3.

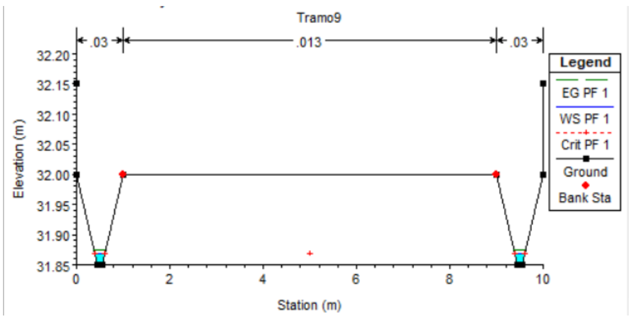

Fig. 2. River station 500m for the green ditch

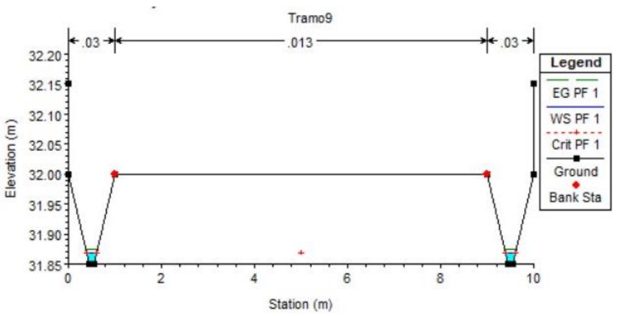

Fig. 3. River station 500m for the traditional ditch

In Figures 2 and 3 it can be seen, by way of example, that the representation of the critical flow proposed for hydraulic modeling at the River station 500m is similar for both, green ditch and traditional ditch. The same is evident in the values of the sections of figure 2 and 3 at point 500 that there is a variation of 8.69% and the maximum difference is 0.41.

IV. CONCLUSIONS

Finally, it can be concluded that, applying the most critical flow found in the month of March 2022 through the hydraulic modeling of the green ditch and traditional ditch in the HEC-RAS software, the optimal results seen in the previous item belong to the design with green ditch demonstrating that it is more viable to mitigate flooding in the city of Jaén-Cajamarca. In addition, it is an eco-friendly proposal, which favors the environment, and presents a cheaper application compared to the traditional ditch. Likewise, it consists of shallower excavations which would serve as a quick application to benefit the places where the greatest amount of rainfall occurs.

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