



DISEÑO A ESCALA DE ALCANTARILLA PARA EVALUAR MEJORAS EN SU FUNCIONAMIENTO Y LA SOCAVACIÓN LOCAL EN LA SALIDA

CULVER SCALE DESIGN TO EVALUATE IMPROVEMENTS IN ITS OPERATION AND LOCAL SCOUR AT THE OUTLET

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RESUMEN

El presente trabajo de investigación tiene como objetivo incorporar al diseño de alcantarilla, doble barril, un material que se adhiera a las paredes del conducto para disminuir la velocidad de salida del agua, ubicado en el camino vecinal Macora – Cutash – Jatun Patay, Huánuco. El procedimiento consistió en realizar el diseño de la alcantarilla a una escala 1:20 mediante el software AutoCad. Se usó planchas de acrílico de 5 mm de espesor que simulan el casco de la alcantarilla y mica de 1 mm para simular el doble barril; estos conforman los 3 prototipos de tubería con distintas rugosidades: liso, canto rodado y maleza. Se procedió a colocar los tres prototipos de alcantarilla en el caudal de pendiente variable -ubicado en el laboratorio de hidráulica de la Universidad Ricardo Palma- para poder realizar la toma de datos y observar el comportamiento sometidos a diferentes caudales. Los resultados encontrados después de realizar los 3 ensayos fueron que la velocidad de salida aguas abajo para tubería lisa fue 0.72 m/s, para tubería con rugosidad 0.99 m/s y para tubería con maleza 0.96 m/s, la velocidad de salida disminuye considerablemente junto a los tirantes en los prototipos con rugosidad de canto rodado y maleza. En las conclusiones se observó la finalidad de la colocación de alcantarillas: Disminuir los caudales para evitar porcentajes altos de socavación. Teniendo en cuenta que, al colocar rugosidades de canto rodado y maleza en las tuberías del alcantarillado, los caudales disminuyen más que en la simulación de tuberías lisas.

Palabras clave: Caudal, Socavación, velocidad, alcantarilla



ABSTRACT

The objective of this research work is to incorporate into the double barrel culvert design a material that adheres to the walls of the conduit to reduce the speed of water outlet, located on the Macora - Cutash - Jatun Patay neighborhood road, Huánuco. The procedure consisted of designing the culvert at a 1:20 scale using AutoCad software. 5 mm thick acrylic sheets were used to simulate the culvert shell and 1 mm mica to simulate the double barrel; these make up the 3 pipe prototypes with different roughness: smooth, rounded and weedy. The three culvert prototypes were placed in the flow of variable slope -located in the hydraulics laboratory of the Ricardo Palma University- in order to carry out data collection and observe the behavior when subjected to different flows. The results found after carrying out the 3 tests were that the outlet speed downstream for smooth pipe was 0.72 m/s, for pipe with roughness 0.99 m/s and for pipe with weeds 0.96 m/s, the outlet speed decreases considerably along with to the braces in the prototypes with roughness of boulder and undergrowth. In the conclusions, the purpose of the placement of culverts was observed: To reduce the flows to avoid high percentages of scour. Taking into account that, when placing roughnesses of boulder and brush in the sewer pipes, the flows decrease more than in the simulation of smooth pipes.

Keywords: Flow, Scour, velocity, culvert



INTRODUCTION

In the development of the subject Hydraulic Works Workshop, as part of the training in the field of civil engineering, one of the most important works for water drainage (culvert) is studied in general, [1] where the most frequent problem under the erosive action of water in a stream is scour, which is the main cause for which the structures are out of service, leading to costly repairs and a considerable decrease in the useful life of a hydraulic work.

The practical and economical solution proposed as the main objective of this research is to incorporate into the culvert design a material that adheres to the walls of the conduit to reduce the velocity of water outflow and consequently scour. [2] The general scour decreases when there is the same average velocity of the current when the water carries a large amount of fine particles in suspension.

This technique was developed with the construction of a 2-barrel culvert to scale, corresponding to the width of the variable slope channel of the Hydraulic Laboratory of the Faculty of Engineering of the Universidad Ricardo Palma.

[3] At present, the technologies and scientific knowledge applied to mitigate scour are the projection of dentils at the ends. As well as the TMC culvert.



THEORETICAL BASIS

[4] A culvert is a structure whose main purpose is to bypass an obstacle to the passage of water. In most cases they are applied to road design, i.e. when the flow is intercepted by a road or railway track.

[5] Culverts are calculated to optimally pass the design flow without producing an overflow such that the integrity of the superstructure is compromised. The design flow is based on hydrological considerations, which are discussed in THE Hydrological Cycle. The return period typically varies between 10 and 50 years.

[6] Natural scour are changes in channel elevation that occur over the long term, usually due to natural causes, and can affect the stretch of river in which the culvert is located. The processes that take place are called aggradation and degradation. While aggradation involves the deposition of eroded material from the channel or catchment, degradation involves the lowering or scouring of the channel over relatively long stretches due to a deficit in sediment supply from upstream, contributing to the total scour of the riverbed.

Failure occurs when the depth of the pit, called the scour depth, is of such magnitude that the lower foundation level of the structure is compromised.



Figura 1: Erosión de la margen
Fuente: Falero y Talero (2007)

[7][7] Roughness produces an effect of exchange of the quantity of movement that is translated into what is known as turbulence. This can be produced by the interaction between fluid and



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surfaces as well as by the interaction between the parts of the fluid itself. Thus a smooth surface produces less turbulence than a rough surface. That is, there is less momentum transfer transverse to the direction of flow on smooth surfaces than on rough surfaces. [8]The roughness depends on the greater or lesser unevenness of the internal surfaces of the duct, where the retarding friction occurs.

[9] Minor road works of art are structural elements that eliminate the inaccessibility of a road caused by water. These works of art make it possible to minimise the water flowing on the road, by capturing the water, preventing the water from causing structural damage. The main objective of the minor works of art is to evacuate the water which accumulates as a result of rainfall and runoff to other sources which do not cause damage to the different elements which make up a road. The two main functions of drainage structures are: Control: to collect and manage water for purposes that benefit man. Protection: to defend man's interests against attacks by water.



Figure 2: One-way drainage system

Source: Transport Ministry, Javeriana University (Colombia).






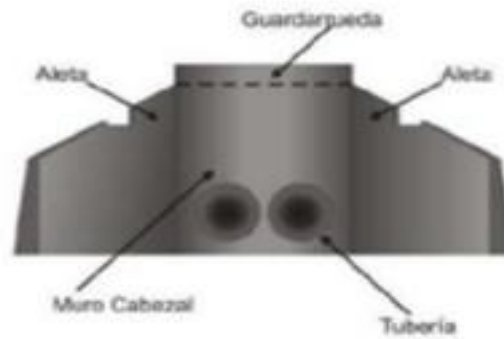
Designación	Sección	Materiales
Rectangular		Hormigón Mampostería Madera
Caño circular		Hormigón Chapa ondulada cincada
Caño abovedado		Chapa ondulada cincada
Caño ovalado		Chapa ondulada cincada
Bóveda		Hormigón Mampostería Hormigón y chapa ondulada

Figure 3: Most commons types of culverts sections



Sources:

Figura 4: Types od culverts

Cornero, G. (1995)

Fuente:Transport ministry, Javeriana University (Colombia)

METHODOLOGICAL FRAMEWORK

To carry out the design of each of the barrels, 30 cm long mica sheets of the pipe with a diameter of 8 cm were used; to be able to carry out the behaviour of the local scour at the outlet of the culvert, 3 prototypes of smooth, rough and weeded pipes were designed.

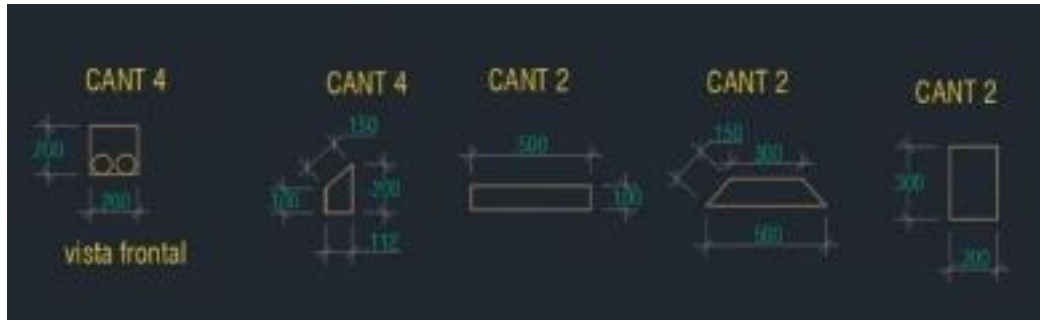


Figure 5. Parts of the culvert were scaled and designed in the AutoCaDi software.

AutoCaD software

Source: Own elaboration



Figure 6: Cutting of the parts for the prototype sewer at reduced scale

Source: Own elaboration

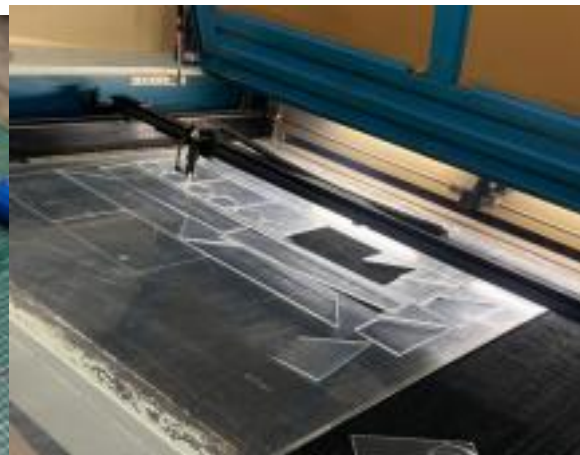


Figura 7: Final Prototipo de a reduced scale sewer

Source: Own elaboration

Reduced scale culvert test with 2 smooth, 2 corrugated and 2 weeded barrels.



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To carry out the test we proceeded to place the prototype culvert in the flow of variable slope to be able to take data and observe the behaviour by subjecting it to different flows, for this first test 5 different flows were carried out, the height of the 21 braces was observed, which 9 were upstream, 8 inside the culvert and 4 downstream.



Figure 8: Placement of the prototype culvert in the variable slope canal
variable slope channel
Source: Own elaboration

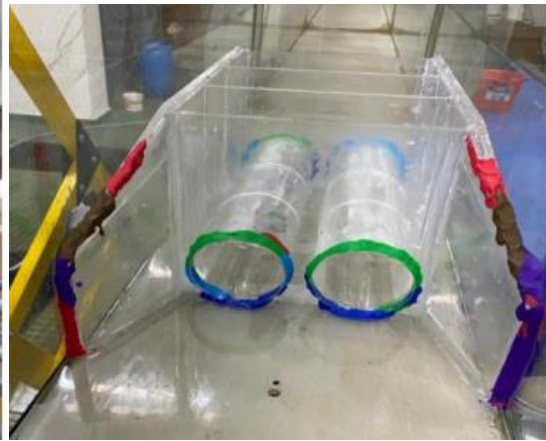


Figure 9: Prototype culvert ready for laboratory testing
Source: Own elaboration

Current meter method : In order to calculate the water velocity measurement, the current meter method was used. The depths at which the velocities are measured with the current meter are found as a function of the height of the water flow.



Figure 10: Placement of current meter to calculate water velocities Source: Own elaboration



Figure 11: Measuring of the braces to be recorded on the blackboard Source: Own elaboration

Volumetric Method : The application of this method is to determine spring flows, i.e. very small flows, which in irrigation projects is used to determine the capacity of a night reservoir to be stored with spring water. This method is based on measuring the time it takes to fill a bucket of a known volume. Dividing the capacity of the bucket (litres) by the time taken (seconds) gives the flow rate in l/s, as shown in the following formula:

$$\text{Caudal (l/s)} Q = \frac{\text{Volumen del balde (litros)}}{\text{Tiempo que demora en llenarse (s)}}$$



Figure 12: Application of the volumetric method

Source: Own elaboration



Figure 13: Weight of bucket with water at laboratory conditions

Source: Own elaboration

CONTENT AND DESCRIPTION OF THE WORK

Design of a double barrel culvert:

The design of a double barrel culvert of a work in execution located in the Macora - Cutash - Jatun Patay neighbourhood road, district of Marías - province of Dos de Mayo - Huánuco, at a reduced scale of 1:20 which was made a model of acrylic of 5 mm of thickness. The reduced scale design of this culvert was carried out in AutoCAD software by dimensioning each of its parts and then proceeding to the cutting of each of the pieces.



Figure 14: Location of the study area
Fuente: Google Earth Pro

Figure 15: Full-scale culvert in operation
Source: Own elaboration

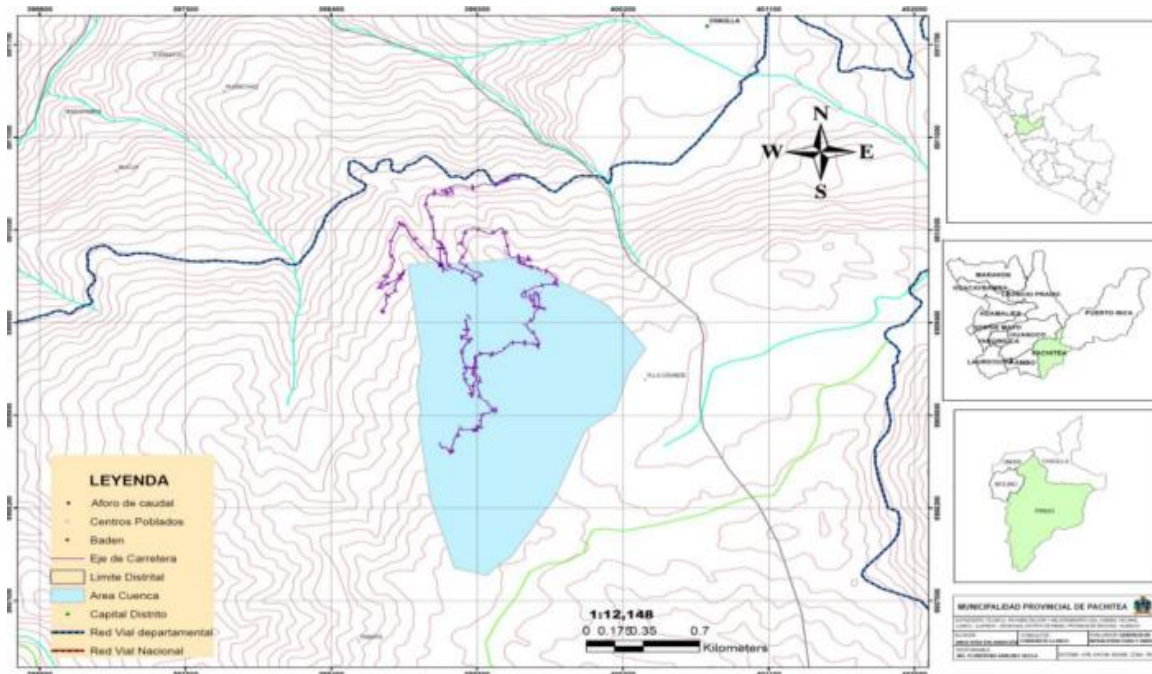


Figure 14: Map of project location project
Source: Technical file 2014

1.1. Temperature

Its average temperature fluctuates between 15 and 20 °C, with maximum temperatures between 22 and 29° C in the forest, and minimum temperatures between 10 and 15° C during the winter.

1.2. Climate

According to the Climate Classification Map of Peru, elaborated by SENAMHI, the project is located in a temperate and rainy climate zone.

The dominant climate of the district is cold, with a notable difference in temperature between day and night and rainfall between the months of December and March.

1.3. Soil

The soil of the district is clayey and sandy, with rocky areas and areas suitable for cultivation; its geographical features are: ravines and deep cracks in the hills that cause landslides, landslides and rock slides.

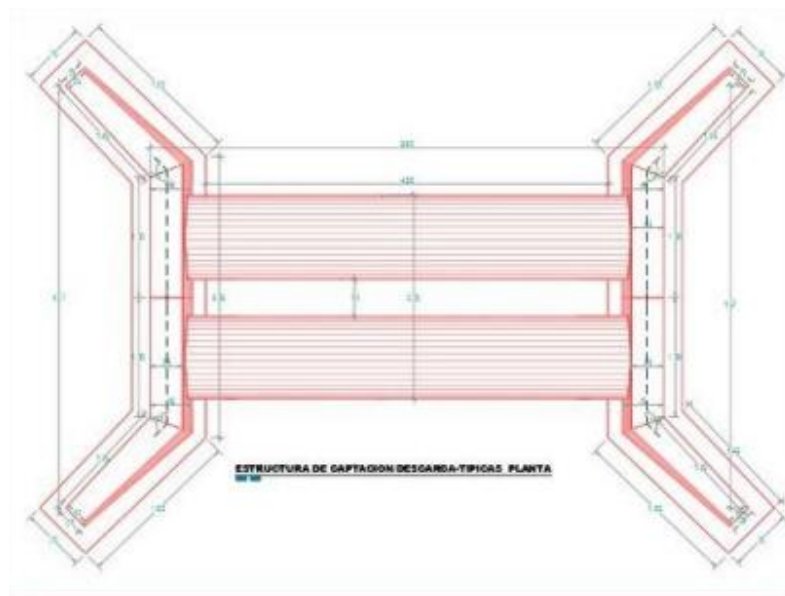


Figure 15: Drawing of actual culvert
made in AutoCAD

Source: Own elaboration

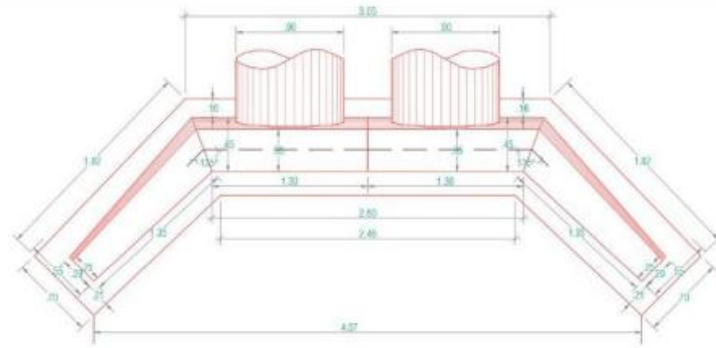


Figure 16: Front view of culvert
real made in AutoCAD
Source: Own elaboration

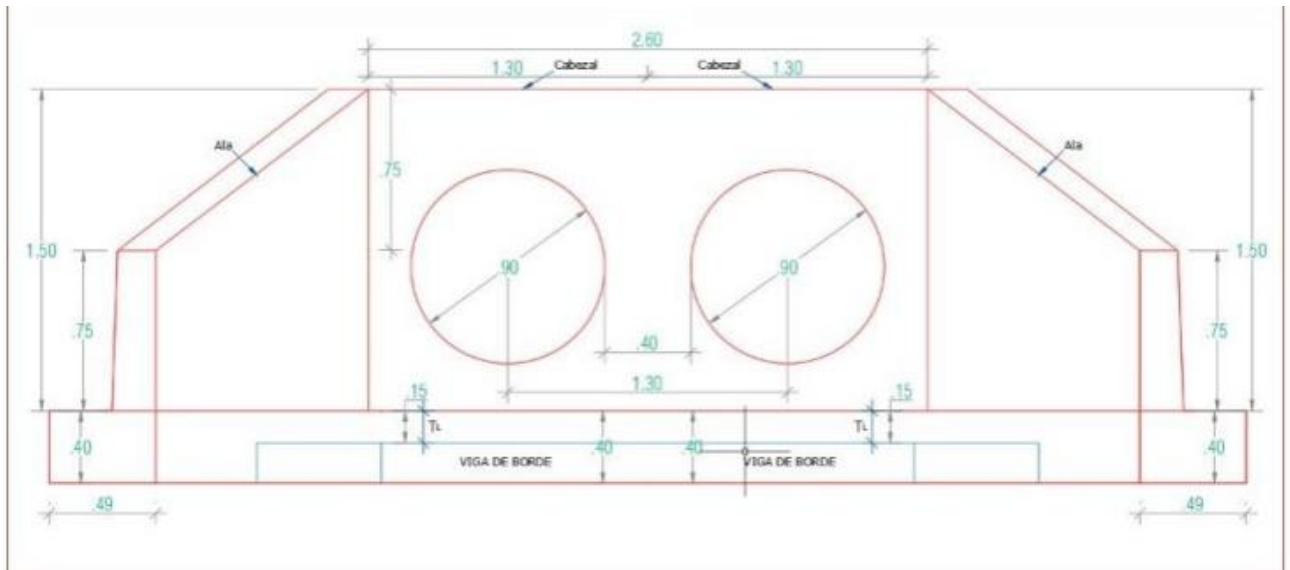


Figure 17: Front view of culvert
real made in AutoCAD
Source: Own elaboration



CALCULATIONS AND RESULTS

First of all, the flow rates must be calculated, for which two methods were used, one with the use of the Correntometer equipment and the other with the volumetric method, for which the following formulas were used.

For $n \leq 0.87$; $v(m/s) = 0.2389 * n + 0.017$ where: $n =$ revolution in 1 second.

$0.87 < n \leq 9.8$; $v(m/s) = 0.2550 * n + 0.013$ $v =$ flow rate.

$Q = Vol/t$ $Q =$ caudal, $Vol =$ Volumen.

$Q = Vel * A$ $A =$ Área, $Vel =$ Velocidad.

Table 1

Calculations of the average flow rates of the first laboratory test with smooth pipe by volumetric method.

	Q	m(recip) Kg	m(recip. + agua) Kg	m (Kg)	Vol	t(seg)	Q(m3/s)	Promedio Q
T U B E R Í A L I S A	Q1	0.62	7.52	6.9	0.0069	24.25	0.000285	0.000287527
		0.62	8.3	7.68	0.0077	26.73	0.000288	
		0.62	9.16	8.54	0.0086	29.55	0.000290	
	Q2	0.62	9.68	9.06	0.0091	9.24	0.000982	0.001312509
		0.62	9.9	9.28	0.0093	6.79	0.001369	
		0.62	7.82	7.2	0.0072	4.55	0.001586	
	Q3	0.96	9.62	8.66	0.0087	2.01	0.004317	0.003724504
		0.96	14.18	13.22	0.0132	3.84	0.003450	
		0.96	10.48	9.52	0.0095	2.8	0.003407	
Q4	0.96	10.08	9.12	0.0091	1.73	0.005282	0.005732031	
	0.96	10.72	9.76	0.0098	1.67	0.005856		
	0.96	11.54	10.58	0.0106	1.75	0.006058		
Q5	0.96	12.66	11.7	0.0117	1.94	0.006043	0.006299154	
	0.96	13.14	12.18	0.0122	1.93	0.006324		
	0.96	8.26	7.3	0.0073	1.12	0.006531		

Source: Own elaboration

Table 2

Calculations of the average flow rates of the second laboratory with rough pipe by



volumetric method.

T U B E R Í A R U G O S A	Q1	0.62	7.66	7.04	0.0071	13.34	0.000529	0.000489312
		0.62	6.62	6	0.0060	12.47	0.000482	
		0.62	5.92	5.3	0.0053	11.62	0.000457	
	Q2	0.62	6.54	5.92	0.0059	5.4	0.001098	0.001110249
		0.62	5.7	5.08	0.0051	4.57	0.001114	
		0.62	6.48	5.86	0.0059	5.25	0.001118	
	Q3	0.96	5.78	4.82	0.0048	2.07	0.002333	0.002362299
		0.96	6.9	5.94	0.0060	2.46	0.002419	
		0.96	7.18	6.22	0.0062	2.67	0.002334	
	Q4	0.96	7.26	6.3	0.0063	1.64	0.003849	0.003893988
		0.96	7.02	6.06	0.0061	1.48	0.004103	
		0.96	7.4	6.44	0.0065	1.73	0.003730	
	Q5	0.96	11	10.04	0.0101	1.32	0.007621	0.00649496
		0.96	10.8	9.84	0.0099	1.72	0.005732	
		0.96	12.28	11.32	0.0113	1.85	0.006131	

Source: Own elaboration

Table 3

Calculations of the average flow rates of the third laboratory test with weeded pipe by volumetric method.

T U B E R Í A M A R Í A Z A C O N	Q1	0.62	4.96	4.34	0.0043	3.28	0.001326	0.001324061
		0.62	5.28	4.66	0.0047	3.51	0.001330	
		0.62	4.14	3.52	0.0035	2.68	0.001316	
	Q2	0.62	5.96	5.34	0.0054	3.46	0.001546	0.001633142
		0.62	5.22	4.6	0.0046	2.91	0.001584	
		0.62	5.74	5.12	0.0051	2.9	0.001769	
	Q3	0.96	6.5	5.54	0.0056	2.07	0.002682	0.002703184
		0.96	7.18	6.22	0.0062	2.13	0.002926	
		0.96	4.88	3.92	0.0039	1.57	0.002502	
	Q4	0.96	5.46	4.5	0.0045	1.17	0.003854	0.003437657
		0.96	6.1	5.14	0.0052	1.68	0.003066	
		0.96	6.04	5.08	0.0051	1.5	0.003393	
	Q5	0.96	8.5	7.54	0.0076	1.11	0.006806	0.005980953
		0.96	5.5	4.54	0.0045	0.76	0.005986	
		0.96	7.18	6.22	0.0062	1.21	0.005151	

Source: Own elaboration

Calculations of the average flow rates of the first laboratory test by the current meter method. method.



Table 4

Table of calculation of average flow rates of test 1 for smooth pipe by correntometer method

T U B E R Í A	Q3	20	13	0.65	0.1723	7.5	0.0225	0.003876	0.003876
		20	13	0.65	0.1723	7.5	0.0225	0.003876	
		20	13	0.65	0.1723	7.5	0.0225	0.003876	
	Q4	20	15	0.75	0.1962	9.5	0.0285	0.005591	0.005591
		20	15	0.75	0.1962	9.5	0.0285	0.005591	
		20	15	0.75	0.1962	9.5	0.0285	0.005591	
	Q5	20	18	0.9	0.2325	10	0.0300	0.006975	0.006975
		20	18	0.9	0.2325	10	0.0300	0.006975	
		20	18	0.9	0.2325	10	0.0300	0.006975	

Source: Own elaboration

Table of calculation of average flow rates of the corrugated pipe test by correntometer method

T U B E R Í A	Q3	20	12	0.6	0.1603	6.15	0.01845	0.002958	0.002958
		20	12	0.6	0.1603	6.15	0.01845	0.002958	
		20	12	0.6	0.1603	6.15	0.01845	0.002958	
	Q4	20	13	0.65	0.1723	7.30	0.02190	0.003773	0.003773
		20	13	0.65	0.1723	7.30	0.02190	0.003773	
		20	13	0.65	0.1723	7.30	0.02190	0.003773	
	Q5	20	16	0.8	0.2081	8.00	0.02400	0.004995	0.003233
		20	15	0.75	0.1962	2.50	0.00750	0.001471	

Source: Own elaboration



Tabla 6

Cuadro de cálculo de caudales promedio del ensayo por tubería de maleza por método correntómetro

T U B E R Í A	M A L E Z A	Q3	20	12	0.6	0.1603	4	0.012	0.00192408	0.00192408
			20	12	0.6	0.1603	4	0.012	0.00192408	
			20	12	0.6	0.1603	4	0.012	0.00192408	
	Q4	20	17	0.85	0.2201	5.5	0.0165	0.003631073	0.003631073	
		20	17	0.85	0.2201	5.5	0.0165	0.003631073		
		20	17	0.85	0.2201	5.5	0.0165	0.003631073		
	Q5	20	17	0.85	0.2201	7.8	0.0234	0.005149521	0.00362042	
		20	21	1.05	0.2708	5	0.015	0.00406125		
		20	17	0.85	0.2201	2.5	0.0075	0.001650488		

Source: Own elaboration

Datos de las alturas de los tirantes del primer ensayo con tubería lisa, rugosa y con maleza.

Tabla 7

Cuadro de tirantes del primer ensayo con tubería lisa

1 ^{er} Ensayo - Tubería lisa																					
	Aguas Arriba									Alcantarilla								Aguas abajo			
	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	Y ₆	Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁	Y ₁₂	Y ₁₃	Y ₁₄	Y ₁₅	Y ₁₆	Y ₁₇	Y ₁₈	Y ₁₉	Y ₂₀	Y ₂₁
Q ₁	2.30	2.30	2.30	2.30	2.25	2.15	2.10	2.10	2.00	1.90	1.98	1.85	1.80	1.75	1.40	1.25	1.20	1.18	1.30	1.25	1.20
Q ₂	4.80	4.80	4.80	4.80	4.75	4.75	4.80	4.85	4.70	3.70	3.40	3.55	3.20	3.40	3.40	3.60	2.30	2.20	2.20	2.10	2.40
Q ₃	7.20	7.20	7.20	7.20	7.20	7.19	7.18	7.19	7.19	5.60	5.40	4.70	5.10	5.00	4.80	3.60	2.60	2.85	3.25	2.65	2.60
Q ₄	9.15	9.15	9.20	9.15	9.15	9.20	9.30	9.25	9.20	7.20	6.40	5.60	5.90	6.00	5.40	4.40	4.30	3.80	4.20	3.40	2.70
Q ₅	10.10	10.10	10.00	10.00	10.10	10.10	10.10	10.00	9.90	7.20	7.30	6.20	5.90	6.50	6.00	5.50	3.50	3.51	4.13	4.20	2.81

Source: Own elaboration

Tabla 8

Cuadro de tirantes del segundo ensayo tubería rugosa

2do Ensayo - Tubería con rugosidad																											
	Aguas Arriba								Alcantarilla								Aguas abajo										
	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	Y ₆	Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁	Y ₁₂	Y ₁₃	Y ₁₄	Y ₁₅	Y ₁₆	Y ₁₇	Y ₁₈	Y ₁₉	Y ₂₀	Y ₂₁	Y ₂₂	Y ₂₃	Y ₂₄	Y ₂₅	Y ₂₆	Y ₂₇
Q ₁	3.00	2.90	2.80	2.80	2.80	2.80	2.70	2.70	2.70	2.60	2.60	2.60	2.40	2.00	2.00	1.80	1.30	1.30	1.30	1.40	1.40	1.15	1.60	1.50	1.60	1.50	1.50
Q ₂	4.20	4.30	4.30	4.30	4.20	4.20	4.20	4.20	4.20	3.60	3.60	3.50	3.50	3.00	2.80	2.30	1.50	1.90	1.80	1.90	2.00	2.20	2.30	2.20	2.30	2.10	2.00
Q ₃	5.90	5.90	5.90	5.90	5.90	6.00	6.00	6.00	6.20	5.50	5.40	5.20	4.80	4.70	4.00	3.70	2.10	2.50	2.50	2.10	3.20	2.50	3.20	3.10	3.00	3.00	2.90
Q ₄	7.10	7.20	7.20	7.20	7.20	7.30	7.30	7.30	7.30	5.80	6.20	6.50	5.90	5.10	4.00	3.50	4.00	2.50	2.30	2.40	2.50	2.50	3.40	3.60	3.75	3.70	3.60
Q ₅	10.20	10.20	10.20	10.20	10.30	10.30	10.40	10.30	10.20	7.00	7.20	6.50	7.00	7.20	6.50	5.50	3.00	3.40	4.50	3.60	2.80	2.70	2.30	2.00	2.20	3.10	2.90

Source: Own elaboration

Table 9
Tie rod table of the third weed pipe trial

3^{er} Ensayo - Tubería con maleza

	Aguas Arriba											Alcantarilla								Aguas abajo									
	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	Y ₆	Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁	Y ₁₂	Y ₁₃	Y ₁₄	Y ₁₅	Y ₁₆	Y ₁₇	Y ₁₈	Y ₁₉	Y ₂₀	Y ₂₁	Y ₂₂	Y ₂₃	Y ₂₄	Y ₂₅	Y ₂₆	Y ₂₇	Y ₂₈	Y ₂₉
Q ₁	4.60	4.60	4.65	4.60	4.60	4.60	4.65	4.60	4.60	4.60	4.50	4.50	4.50	4.30	4.50	4.00	3.50	2.60	1.30	1.80	1.90	0.90	1.30	1.30	1.30	1.50	1.60	1.60	1.80
Q ₂	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.90	4.95	4.70	4.60	4.50	4.30	4.30	4.15	3.30	2.40	2.40	2.30	2.00	1.40	1.40	1.40	1.40	1.50	1.60	1.80	1.50
Q ₃	6.00	6.00	6.00	6.00	6.10	6.05	6.10	6.15	6.05	5.30	5.30	5.30	5.30	5.05	4.90	5.00	4.00	2.40	2.50	2.40	2.30	1.10	1.60	1.60	1.50	1.60	1.90	1.80	1.90
Q ₄	7.40	7.40	7.40	7.50	7.517	7.60	7.60	7.60	7.60	7.50	7.40	6.10	6.30	5.90	5.70	5.50	3.80	2.80	2.90	3.00	2.15	2.10	2.10	2.10	1.90	1.60	2.20	2.00	2.00
Q ₅	9.70	9.70	9.70	9.70	9.80	9.80	9.90	9.90	9.90	9.90	9.90	8.50	8.40	8.30	8.10	8.10	6.30	4.50	3.90	3.80	5.30	5.00	2.20	2.20	2.10	1.90	2.30	2.80	2.30

Source: Own elaboration

Data processing with HEC - RAS:

Once the flow rates have been calculated and the measurements of the tie rods have been taken, they are processed as data that are entered into the software so that after a run of the program, the software can obtain a table of the results of the velocities in each section and also to be able to observe the hydraulic modelling of the culvert and analyse them.

Run for the smooth pipe in the program HEC-RAS

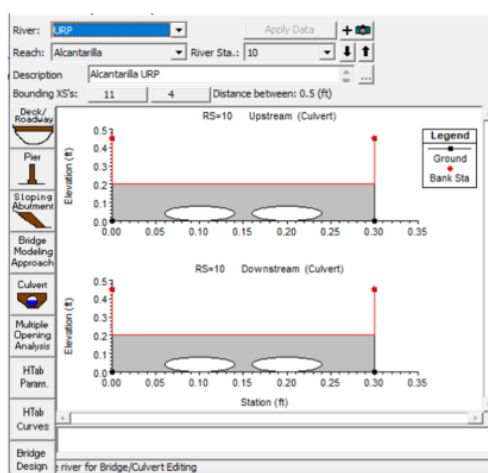


Figure 18: Design of the culvert section
Source: Own elaboration

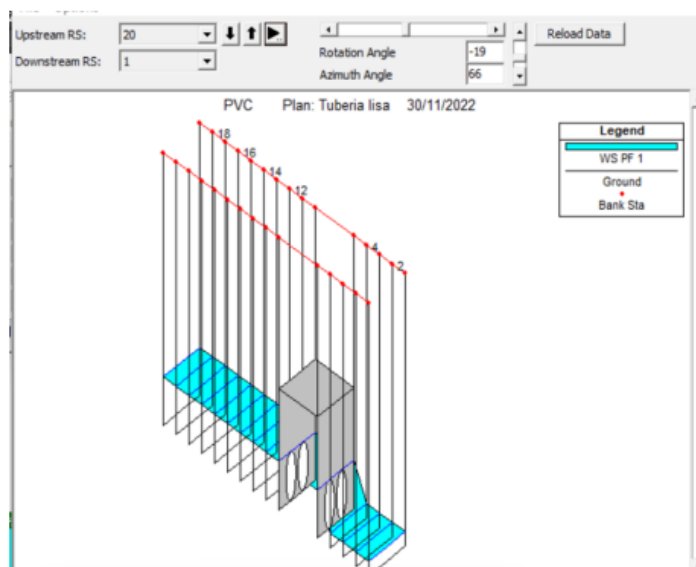


Figure 18: Braces and programme run
Source: Own elaboration

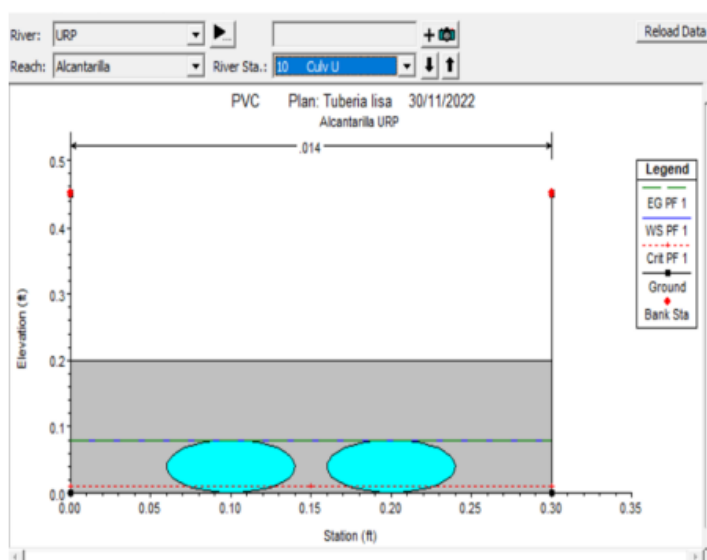


Figure 19: Flow rate where it saturates the pipe inlet
pipe
Source: Own elaboration



Description : Tr

Enter/Edit Number of Profiles (32000 max): 5 Reach Boundary Conditions ...

Locations of Flow Data Changes

River: URP Add Multiple...

Reach: Alcantarilla River Sta.: 20 Add A Flow Change Location

Flow Change Location			Profile Names and F					
River	Reach	RS	PF 1	PF 2	PF 3	PF 4	PF 5	
1	URP	Alcantarilla	20	0.000287	0.00131	0.00387	0.00559	0.006975
2	URP	Alcantarilla	18	0.000287	0.00131	0.00387	0.00559	0.006975
3	URP	Alcantarilla	17	0.000287	0.00131	0.00387	0.00559	0.006975
4	URP	Alcantarilla	16	0.000287	0.00131	0.00387	0.00559	0.006975
5	URP	Alcantarilla	15	0.000287	0.00131	0.00387	0.00559	0.006975
6	URP	Alcantarilla	14	0.000287	0.00131	0.00387	0.00559	0.006975
7	URP	Alcantarilla	13	0.000287	0.00131	0.00387	0.00559	0.006975
8	URP	Alcantarilla	12	0.000287	0.00131	0.00387	0.00559	0.006975
9	URP	Alcantarilla	11	0.000287	0.00131	0.00387	0.00559	0.006975
10	URP	Alcantarilla	4	0.000287	0.00131	0.00387	0.00559	0.006975
11	URP	Alcantarilla	3	0.000287	0.00131	0.00387	0.00559	0.006975
12	URP	Alcantarilla	2	0.000287	0.00131	0.00387	0.00559	0.006975
13	URP	Alcantarilla	1	0.000287	0.00131	0.00387	0.00559	0.006975

Figure 20: The 5 different calculated flow rates

Source: Own elaboration

HEC-RAS Plan: Plan p02 River: URP Reach: Alcantarilla Profile: PF 5

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Alcantarilla	20	PF 5	0.01	0.00	0.09		0.09	0.000253	0.25	0.03	0.30	0.15
Alcantarilla	18	PF 5	0.01	0.00	0.09		0.09	0.000253	0.25	0.03	0.30	0.15
Alcantarilla	17	PF 5	0.01	0.00	0.09		0.09	0.000254	0.25	0.03	0.30	0.15
Alcantarilla	16	PF 5	0.01	0.00	0.09		0.09	0.000254	0.25	0.03	0.30	0.15
Alcantarilla	15	PF 5	0.01	0.00	0.09		0.09	0.000254	0.25	0.03	0.30	0.15
Alcantarilla	14	PF 5	0.01	0.00	0.09		0.09	0.000254	0.25	0.03	0.30	0.15
Alcantarilla	13	PF 5	0.01	0.00	0.09		0.09	0.000254	0.25	0.03	0.30	0.15
Alcantarilla	12	PF 5	0.01	0.00	0.09		0.09	0.000255	0.25	0.03	0.30	0.15
Alcantarilla	11	PF 5	0.01	0.00	0.09	0.02	0.09	0.000255	0.25	0.03	0.30	0.15
Alcantarilla	10		Culvert									
Alcantarilla	4	PF 5	0.01	0.00	0.03		0.04	0.005867	0.72	0.01	0.30	0.71
Alcantarilla	3	PF 5	0.01	0.00	0.03		0.04	0.006496	0.75	0.01	0.30	0.75
Alcantarilla	2	PF 5	0.01	0.00	0.03	0.02	0.04	0.007490	0.78	0.01	0.30	0.80
Alcantarilla	1	PF 5	0.01	0.00	0.02	0.02	0.04	0.014849	0.97	0.01	0.30	1.11

Figure 21: Results of velocities in each section

Source: Own elaboration

Rough pipe run in the HEC-RAS programme

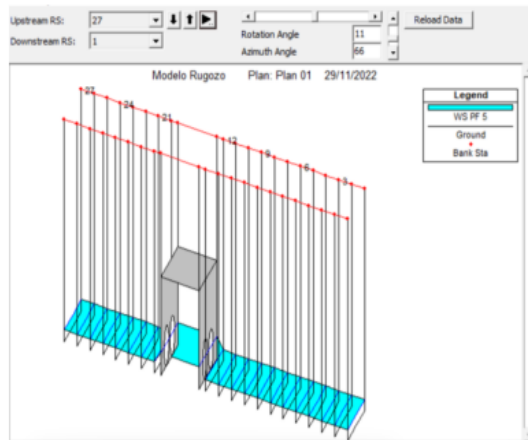


Figure 22: Braces and programme run
Source: Own elaboration

Description: Grupo 1

Enter/Edit Number of Profiles (32000 max): 5 Reach Boundary Conditions ...

Locations of Flow Data Changes

River: URP River Sta.: 27

River	Reach	RS	PF 1	PF 2	PF 3	PF 4	PF 5
1 URP	Alcantarilla	27	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
2 URP	Alcantarilla	26	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
3 URP	Alcantarilla	25	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
4 URP	Alcantarilla	24	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
5 URP	Alcantarilla	23	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
6 URP	Alcantarilla	22	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
7 URP	Alcantarilla	21	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
8 URP	Alcantarilla	20	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
9 URP	Alcantarilla	12	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
10 URP	Alcantarilla	11	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
11 URP	Alcantarilla	10	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
12 URP	Alcantarilla	9	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
13 URP	Alcantarilla	8	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
14 URP	Alcantarilla	7	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
15 URP	Alcantarilla	6	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
16 URP	Alcantarilla	5	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03
17 URP	Alcantarilla	4	4.89312E-04	1.110249E-0	2.362299E-0	3.893988E-0	6.49496E-03

Figure 23: The 5 different calculated flow rates
Source: Own elaboration

HEC-RAS Plan: Plan 02 River: URP Reach: Alcantarilla Profile: PF 5

Reach	River Sta	Profile	Q Total (cfs)	Min Ch Vel (ft/s)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope	Vel Chf (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude #	Ch #
Alcantarilla	27	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	26	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	25	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	24	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	23	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	22	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	21	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	20	PF 5	0.01	0.00	0.02	0.02	0.04	0.010010	0.92	0.01	0.30	1.06	
Alcantarilla	19	Culvert											
Alcantarilla	12	PF 5	0.01	0.00	0.02	0.02	0.04	0.009445	0.90	0.01	0.30	1.03	
Alcantarilla	11	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	10	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	9	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	8	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	7	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	6	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	5	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	4	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	3	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	2	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	
Alcantarilla	1	PF 5	0.01	0.00	0.02	0.02	0.04	0.011491	0.96	0.01	0.30	1.13	

Figure 24: Results of velocities in each section
Source: Own elaboration

Run for the pipeline with weeds in the HEC-RAS programme.

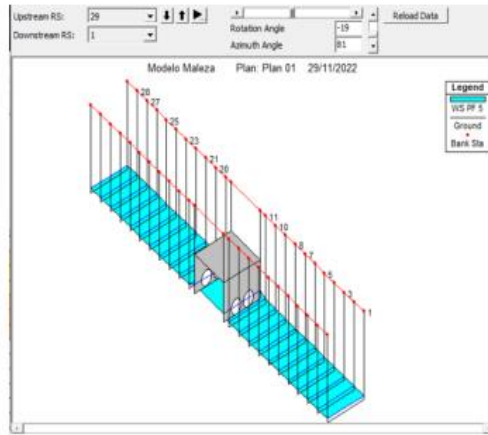


Figure 25: Braces and programme run
Source: Own elaboration

Description : Tr

Enter/Edit Number of Profiles (32000 max): 5 Reach Boundary Conditions ...

Locations of Flow Data Changes

River: URP Add Multiple...

Reach: Alcantarilla River Sta.: 29 Add A Flow Change Location

Flow Change Location			Profile Names and					
River	Reach	RS	PF 1	PF 2	PF 3	PF 4	PF 5	
1	URP	Alcantarilla	29	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
2	URP	Alcantarilla	28	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
3	URP	Alcantarilla	27	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
4	URP	Alcantarilla	26	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
5	URP	Alcantarilla	25	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
6	URP	Alcantarilla	24	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
7	URP	Alcantarilla	23	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
8	URP	Alcantarilla	22	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
9	URP	Alcantarilla	21	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
10	URP	Alcantarilla	20	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
11	URP	Alcantarilla	19	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
12	URP	Alcantarilla	11	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
13	URP	Alcantarilla	10	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
14	URP	Alcantarilla	9	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
15	URP	Alcantarilla	8	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
16	URP	Alcantarilla	7	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
17	URP	Alcantarilla	6	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0
18	ID0	Alcantarilla	6	1.324061E-0	1.633142E-0	2.703184E-0	3.437657E-0	5.980953E-0

Figure 26: The 5 different calculated flow rates
Source: Own elaboration

HEC-RAS Plan

Reach	River Sta	Profile	Q Total (cfs)	Min Ch Bt (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Ch
Alcantarilla	29	PF 5	0.01	0.00	0.02	0.02	0.03	0.010009	0.89	0.01	0.30	1.06
Alcantarilla	28	PF 5	0.01	0.00	0.02	0.02	0.03	0.011288	0.93	0.01	0.30	1.12
Alcantarilla	27	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	26	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	25	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	24	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	23	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	22	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	21	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	20	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	19	PF 5	0.01	0.00	0.02	0.02	0.03	0.010840	0.92	0.01	0.30	1.10
Alcantarilla	18	Culvert										
Alcantarilla	11	PF 5	0.01	0.00	0.02	0.02	0.03	0.008019	0.83	0.01	0.30	0.95
Alcantarilla	10	PF 5	0.01	0.00	0.02	0.02	0.03	0.008643	0.85	0.01	0.30	0.99
Alcantarilla	9	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	8	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	7	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	6	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	5	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	4	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	3	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	2	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23
Alcantarilla	1	PF 5	0.01	0.00	0.02	0.02	0.04	0.013777	0.99	0.01	0.30	1.23

Figure 27: Results of velocities in each section
Source: Own elaboration

Interpretation of results:

Smooth pipe



$V_e < V_s$

Figure 28: View of smooth culvert barrel

Source: Own elaboration

Rough Pipe

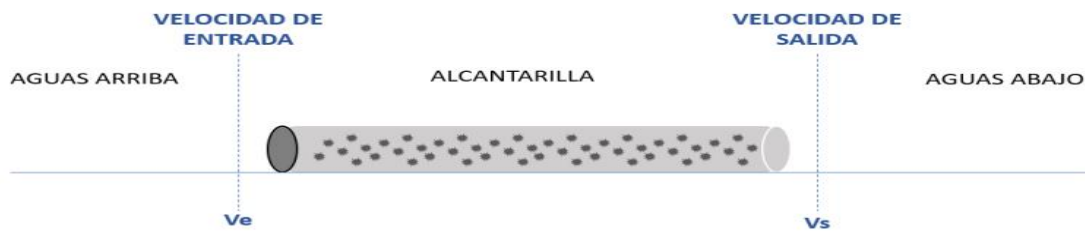


Figure 29: Sewer barrel view with roughness

Source: Own elaboration

Weedy Pipeline

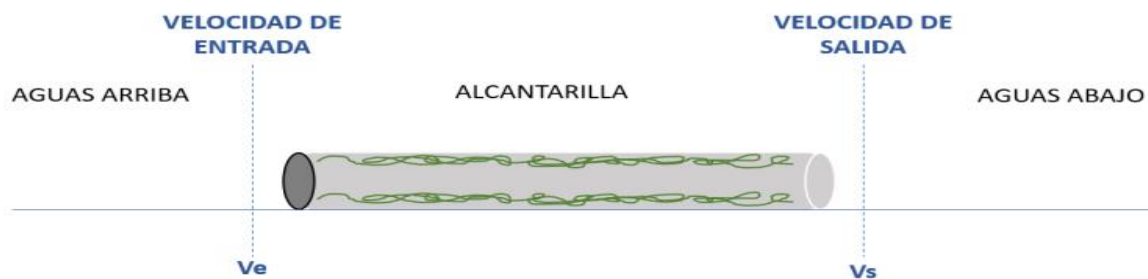


Figure 30: View of sewer barrel with weeds

Source: Own elaboration

Result summary table:

Table 10: Comparison of Speed Difference in the 3 situations.

	Liso	Rugoso	Maleza
Q(m³/s)	6.975x10³	5.981x10³	6.495x10³
Ve(m/s)	0.25	0.92	0.92
Vs(m/s)	0.72	0.99	0.96
△	0.47	0.07	0.04

Own elaboration

Figures 28, 29 and 30 show the behaviour, in a profile view, of the different flows: upstream, inside the culvert and downstream. For the 3 tests carried out, it can be seen how the downstream flows decrease. The most abrupt variations are reflected in (Figure 30) when the 5 curves tend to decrease and approach a common head. This behaviour is positive, since a lower head indicates a lower outflow velocity and therefore a lower percentage of scour effects.

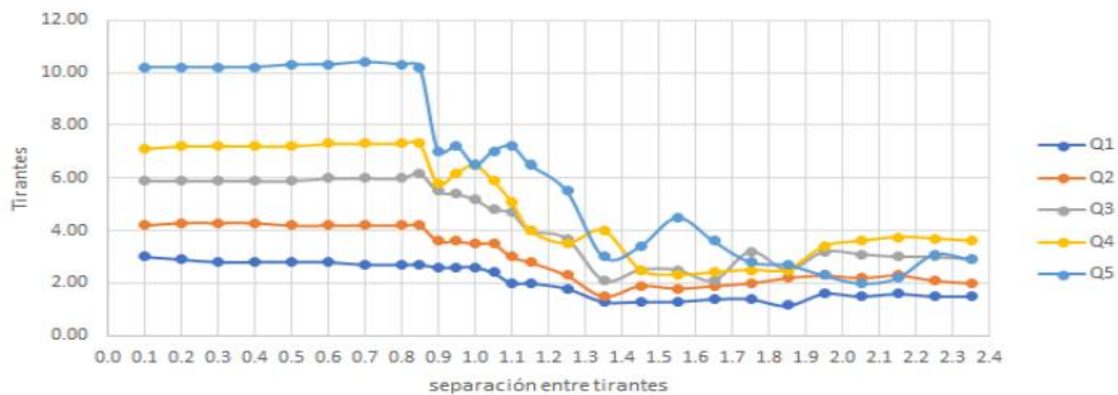


Figure 31: Behaviour in the pebble sewer test
Source: Own elaboration

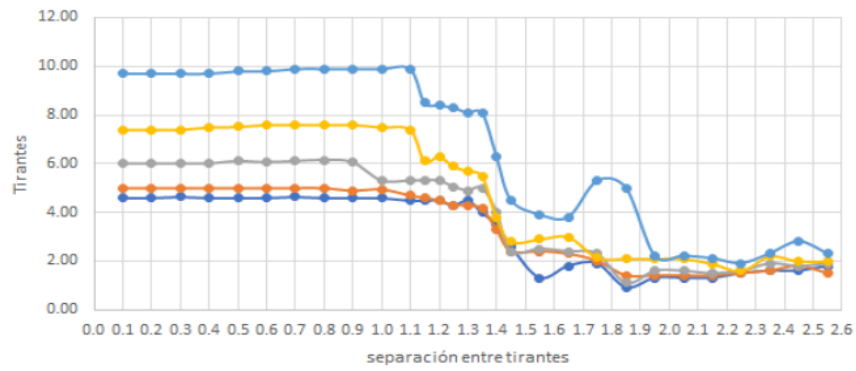


Figure 32: Behaviour in the sewer test with weeds

Source: Own elaboration

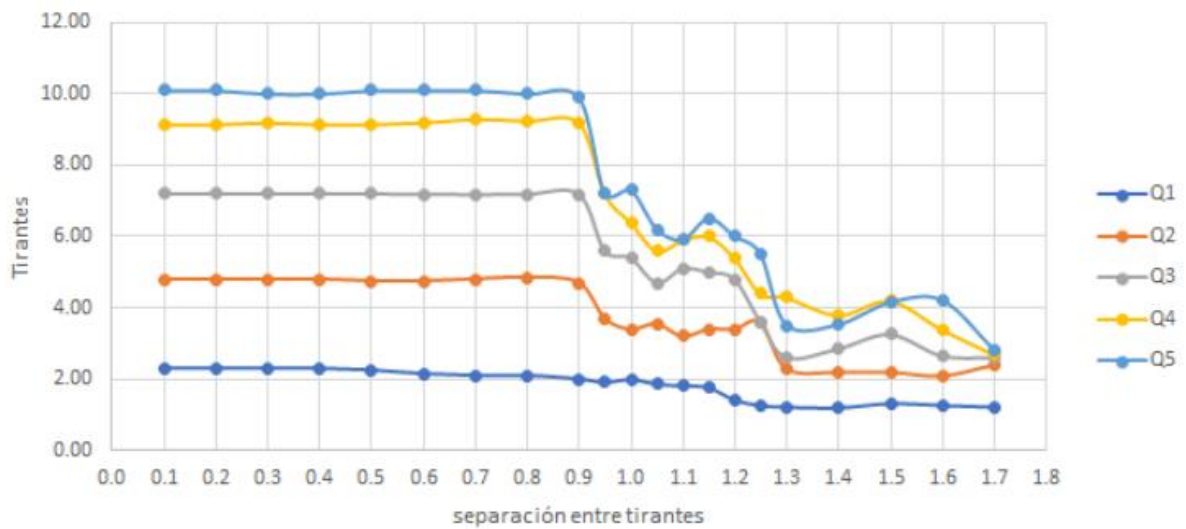


Figure 33: Behaviour in the sewerage test with smooth pipe

Source: Own elaboration



CONCLUSIONS AND RECOMMENDATIONS

- As the roughness in the pipe duct increases the outlet velocity decreases.
- The outlet velocity will always be greater than the inlet velocity.
- It is possible to create a material with roughness characteristics that will decrease the outlet velocity and consequently give a longer life to the culvert.
- The solution to the problem of scour will greatly reduce the cost of repairs and increase the life of the culvert.
- Well-functioning culverts ensure the integration of communities

RECOMMENDATIONS

- It is recommended to study and analyse non-polluting materials to be used as a bonding layer in the culvert conduit using the findings of this research.
- A study of the budget for culvert repair under this method should be made and compared with the budget for a new culvert and to know the more specific economic feasibility.



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