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Modelling of a Stilling Basins with Sloping Apron in IBER to Improve Efficiency in High-slope Rivers

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Modelling of a Stilling Basins with Sloping Apron in IBER to Improve Efficiency in High-slope Rivers

Y Zabaleta[1,*], O K Espejo[1], J M Fernández[1] and S Santos[1]

[1]Civil Engineering, Peruvian University of Applied Sciences, Prolongación Primavera 2390, Santiago de Surco, Lima, Perú.

u201616464@upc.edu.pe

Abstract. This research shows the influence of stilling basin slopes on energy loss in rivers with a high gradient. This study takes as a case San Pedro water intake (Ayacucho, Peru). The main objective is to improve efficiency of stilling basins in rivers with high slope. Five dissipation pools of different slopes were modelled: 0%, 1.52%, 3.04%, 4.56% and 6.08% to propose the optimum pool among these, for the San Pedro intake. Results were validated by means of a Sensitivity Analysis, trough comparison with the results of previous investigation and results of modelling San Pedro river with HEC-RAS and IBER. It was obtained that the steeper the slope of the stilling basin, the higher the specific energy loss, the higher the output rate, the longer the stilling basin. It can be concluded that the 3.04% slope stilling basin is the most appropriate for the 6.08% slope river since the slope variation is not abrupt as in the case of the horizontal one, that is, 30% more energy loss with respect to the horizontal pool and velocity and Froude results similar to the modelling of the San Pedro river.

1. Introduction

Hydraulic structures placed in natural riverbeds, such as barrages; cause a change in the natural flow, which is why they have an evacuation system that ensures the controlled output of the flow. These systems are called spillways and have a stilling basin to transform supercritical to subcritical flow. In general, the water outlet has a higher kinetic energy and must be dissipated, as it would cause erosion downstream if it were not dissipated. This dissipation occurs by means of the formation of a hydraulic jump in the stilling basin, seeking to join the outlet pipe of the pool with the natural level of the river [1]. These pools are usually horizontal as they ensure a subcritical flow at the outlet, but what happens to rivers with high slopes that does not have subcritical flow?

Flow in the catchment structures located in rivers with high slopes is characterized by a torrential and supercritical regime. The subcritical regime obtained in the stilling basin is once again supercritical due to the difference in slopes between bottom and river natural gradient of the river. In this case, potential energy produced at stilling basin exit, is greater than that of the natural course, generating turbulence and continuous waves. Chanson [1] explains that challenge of a hydraulic jump involves movement of turbulent flow with development of large-scale vortices and trapping of air bubbles at the tip of the jump. He also points to energy transport and dissipation as the key challenges during the weir design process to ensure the life of the structure. Similarly, Legono, Hambali and Krisnayanti [2] show that chaotic jumps of stilling basins downstream of weir cause vibrations in the structure that directly affect it. According to Lempérière et al. [3] the costs of some solutions can be much higher for existing hydraulic structures than for new ones. He also points out that the key to acceptable cost is to reduce probability of failure. Therefore, an optimal solution is sought for designing a stilling basin that guarantees precision and reliability of energy dissipation of supercritical flow at the outlet that reaches the natural flow of the river.

Kumar, M; Kumar, S; Bidhu, S [4] states that with the aim of increasing effectiveness of a sloping channel that maximum energy reduction in relation to the increasing slope of the channel was 45% and according to Pardo's study [5] hydraulic jump in sloping screeds gives high quality efficiency results just like the cases of horizontal screeds. From this, we can model a sloped stilling basin in a CFD program to verify flow behavior, computational fluid dynamics gives reliable results. Thu Hien [6] made a dam spillway physical and numerical model and could prove that the CFD can accurately simulate many real phenomena of the fluids at the stilling basin, since it uses Navier Stokes' equations. By carrying out experimental study by means of numerical modelling of stilling basin with a sloping bottom precision and reliability of energy dissipation of supercritical flow at the pool exit will be guaranteed, reaching the natural supercritical flow of the river. This would provide benefits in improving the performance and safety of the hydraulic structure. The present investigation models flow behaviour in energy dissipation structure located in a high slope river to propose an optimal solution for stilling basin design.

2. Methodology

In order to propose the most efficient stilling basin in high slope rivers, first is necessary to analyse and model main characteristics of flow in river without structures. Based on these data, stilling basins with different slopes will be modelled, results will be compared at pool outlet, so that the one that has the most similarity with the natural river flow characteristics at this point, will be chosen. With the chosen slope, a complementary design accessing the stilling basin will be made for its improvement.

2.1. Hydrological characteristics

Intake is at the San Pedro river, located in Peru, Puquio district, Lucanas province, Ayacucho department. Geographically, in zone 18 L of UTM coordinates approximately 597501.00 m E and 8368463.00 m S. To establish its hydrological and physical characteristics, an investigation carried out by Contreras and Villegas will be used [7]. Table 1 details the main characteristics of the river.

Table 1. Main geomorphological characteristics of the San Pedro river.

San Pedro River					
Length of the river	=	42.10 km	Average slope	=	6.08 %
Average flow	=	6.92 m^3	Design flow rate	=	44.26 m^3/s
Average riverbed width	=	15.40 m	Runoff coefficient	=	0.277
Total annual precipitation average	=	636.43 mm/year	Average annual temperature	=	11.465°C
Average Manning's roughness	=	0.0595	Normal brace	=	0.976 m

2.2. River modelling in HEC-RAS and IBER

The modelling of the river is based on topographic information, in this case NASA's satellite information was used, Alos Palsar, which provides spatial information with a resolution of 12.5 x 12.5 m. From established digital model of elevation, contour lines are generated every 0.50 m by means of Global Mapper program. In the Civil 3D programme river's progressive is created having as a starting point intake, 500m upstream and 100m downstream. The 600 m progressive of the river is created in the opposite direction of the river, as the HEC-RAS programme considers the sections in the opposite direction. Sections are also created at a 10m between them and width of 30m. These values are exported to HEC-RAS. The input parameters are design flow 44,26 m3/s (Q_{50}), average river slope of 6.08% and roughness of 0.0595. The results of the modelling in a three-dimensional view are shown in figure 1.

For the modelling of the surface of San Pedro river in IBER programme, QGIS extension was used. The flow values and the roughness of the river surface were the same as those used in the HEC-RAS modelling; but since this is a 2D software, a 3m unstructured mesh was used and the simulation time was 700s with 10 s intervals. In post-processing of modelling, a longitudinal section is traced along the river to distinguish water level. Profile of this plotted section can be seen in figure 2. To obtain water levels along the river, the results are exported to an Excel spreadsheet.

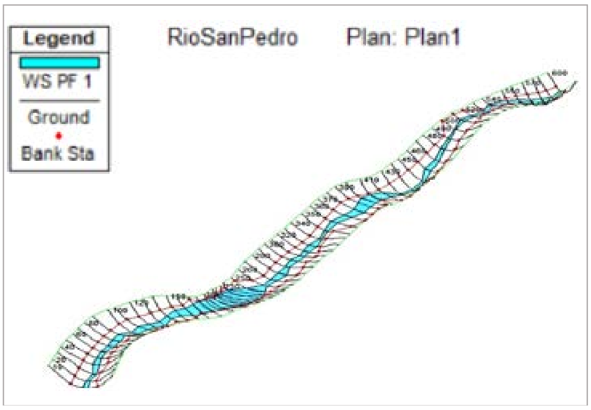

Figure 1. XYZ perspective modelling - HEC-RAS.

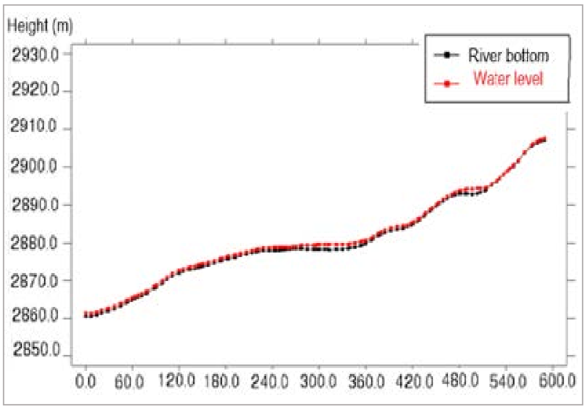

Figure 2. River longitudinal section in IBER.

Hydraulic Characteristics for Q=44.26 m^3/s of San Pedro River were found in area of intake, which corresponds to the progressive 0+500 m of the model. Results were calculated at stilling basin exit. Hydraulic depth of 0.54m was obtained with HEC RAS and 0.52m with IBER. Table 2 shows these results, as well as velocity and Froude number. Velocity values vary in 0.39 m/s. Values of HEC-RAS are higher than IBER's, and with respect of Froude's values, they vary by 0.28. These values confirm that they vary on average by 5.3% between the two softwares. These variations are because in HEC-RAS programme sections have been modelled every 10 m and in IBER programme they have been modelled with the Dem surface with a 3 m mesh.

Table 2. Hydraulic characteristics for Q = 44.26 m^3/s in HEC-RAS and IBER.

Software	Hydraulic depth (m)	Velocity (m/s)	Froude
HEC-RAS	0.54	6.77	4.26
IBER	0.52	6.38	3.98

2.3. *Modelling stilling basin*

San Pedro's intake is of a conventional type due to topographical, geomorphological characteristics and the area chosen for the location. This structure has a raising water level river function and facilitating entry through the intake window by using a "Creager" weir type profile, to reduce pressure all the points of the weir to almost zero. The model geometry covers only the width of intake and characteristics required are summarized in Table 3.

Table 3. San Pedro intake characteristics.

Components	Measures	Components	Measures
Width	15.00 m	Gate height	1.45 m
Hole Threshold Height	0.60 m	Hydraulic jump depths	y_1= 0.69m
Catchment window height	0.60 m		y_2= 2.63m
Catchment window length	3.00 m	Stilling basin length	13.15 m
Weir height	1.40 m	Stilling basin slope	6.08 %
Horizontal length of barrage profile	2.55 m	Protective rock or breakwater	3.00 m
Barrage load height	1.64 m	Weir width	1.00 m

To simulate the real behaviour of an intake in the modelling, the design flow will not only flow through the weir and the 2 gates, but also part of the flow will be captured by the intake window. Measurements will be taken from Table 3, the stilling basin zone will be modelled with 2 slopes, 6.08% and 0.00%. The length of stilling basin with 6.08% slope is already known, for the horizontal stilling basin it is calculated using the formulas of Pardo [4] and Peterka [8] assuming a hydraulic jump. With a Froude of 2.47 downstream of weir, we found major conjugate depth (2.09 m), which was replaced in the Pardo equation for a stilling basin with a slope of 0%, which gave us a length of 10.20m.

Pre-processing of the 6.08% and 0% slope stilling basin in the IBER software involves modelling the geometry as well as meshing it. Intake is imported as a 3D polyline into IBER. Hydrodynamic conditions such as the design flow of 44.26 m3/s (Q50) and internal conditions such as the location of the structures (2 gates, 1 capture and 1 spillway) are assigned. Similarly, roughness is assigned through Manning's coefficient for concrete material of 0.014 over the entire surface of intake and for the rockfill 0.035 in breakwater area. Subsequently, unstructured mesh of 0.2 m is created and the calculation parameters are set with a total simulation time of 80 seconds with results every 1 second. Calculations are then executed and the results are visualised in the post-process.

Results are validated by sensitivity analysis and comparison with design values. With this validation, 3 stilling basin designs are modelled based on change in slope: 4.56%, 3.04% and 1.52%. These slopes are between 0% and 6.08% so that they vary in same proportion. With exported results of the 5 slopes, hydraulic depth, velocity, Froude number and energy at basically the outlet of the stilling basin are compared. Finally, results of energy dissipation are analysed and efficiencies are compared.

3. Results

3.1. Stilling basins modelling results

Result of modelling in IBER programme for horizontal stilling basin is shown by a plan view in figure 3 and Table 4 details values in 3 important points. In catchment area, which corresponds to the first 5 metres, water levels reach 2.61 m. In weir area the water level gradually decreases until it reaches 0.32 m, which is where stilling basin begins. In this zone, corresponding to basin entrance, the velocity is 7.15 m/s and the Froude 4.04 as shown in Table 4. In the basin zone there is no hydraulic jump, meaning that not enough energy is dissipated for the flow to become subcritical, as can be seen from the values in the table, which indicates that at the outlet of the pool the velocity is 6.79 m/s and Froude number is 3.97. The last zone is 3 m breakwater zone where the material changes to rockfill and the water level increases by 5 cm with respect to the outlet of basin, thus the velocity and Froude decrease.

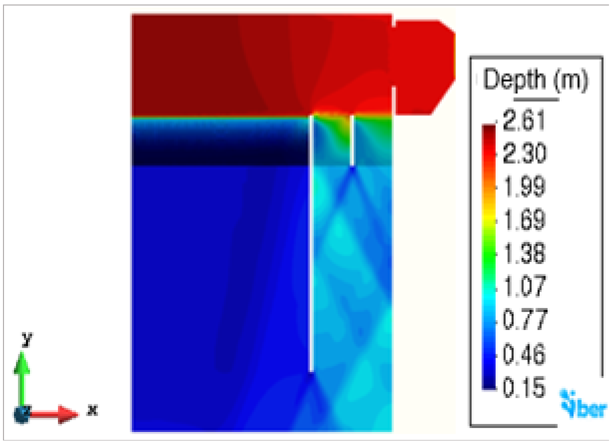

Figure 3. Hydraulic depth plan view - Horizontal stilling basin.

Table 4. Horizontal basin results.

Design Flow Rate (Q_{50}=44.26 m^3/s)			
	Basin entrance	Basin exit	Breakwater exit
Hydraulic depth (m)	0.32	0.30	0.35
Velocity (m/s)	7.15	6.79	5.74
Froude	4.04	3.97	3.11
Energy	2.64	2.57	2.07

Stilling basin with 6.08% slope has 3.48° respect to horizontal. Figure 4 shows plan view of flow through the hydraulic structure and Table 5 shows results for hydraulic depth, velocity, Froude and energy. Catchment area is similar to previous case as flow rate is the same, head reaches 2.62m. The stilling basin area has a slight variation with respect to horizontal modelling as the water level decreases more, in this case by 5cm and in the previous case by 2cm. With respect to values of velocity and Froude in case of this inclined pool, they increase by 0.39 m/s and 1.05. In the breakwater area the values do decrease as in the previous case.

Table 5. Results of 6.08% slope. basin

Design Flow Rate (Q_{50}=44.26 m^3/s)			
	Basin entrance	Basin exit	Breakwater exit
Hydraulic depth (m)	0.31	0.26	0.32
Velocity (m/s)	7.39	7.52	6.40
Froude	3.62	4.67	4.25
Energy	2.65	2.56	1.76

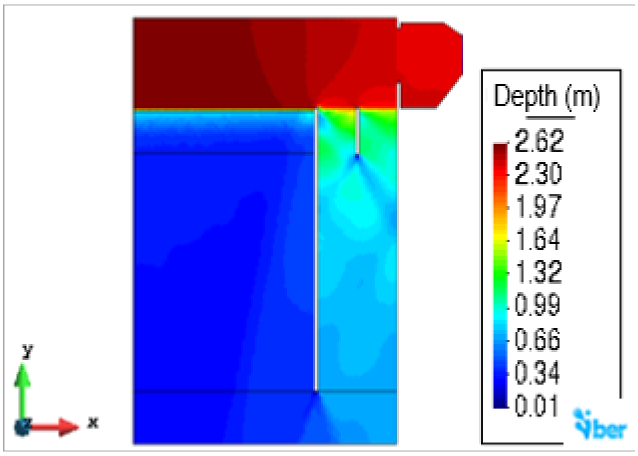

Figure 4. Hydraulic depth plan view - 6.08% stilling basin.

According to both models, the design of the horizontal and inclined pool for a flow of 44,26 m^3/s shows that there is no hydraulic jump in either, which means that there is no energy dissipation. However, according to Fatemeh's study [9], when there is a jump, the factors of turbulence, disturbance and pressure fluctuations increase, which would be more parameters to control.

3.2. Numerical model validation

Information obtained will be validated through a sensitivity analysis [10] in a local approach, that is by changing flow parameter of the numerical model. Likewise, for inclined dissipation pool, the values of model carried out are compared. Furthermore, the results will be compared with the empirically obtained values for the design.

3.3. Sensitivity Analysis

It was used to increase model confidence and represent real circumstances. Input parameter taken is water intake flow, this will allow seeing variation it causes in model. To do sensitivity analysis procedure consisted of modelling in IBER, taking stilling basins of slope 6.08% and 0% with flow parameter design flow rate (Q_{50}= 44,261 m^3/s), average maximum flow rate (Q_{MP}= 42.61 m^3/s), and extraordinary flow rate (Q_E= 27.91 m^3/s).

Figures 5 and 6 show hydraulic depths for horizontal basin and stilling basin with a sloping bottom. In both figures similar flow behaviours. It is clearly observed that with a higher flow, water level over the weir increases. Hydraulic depths for discharges 44.261 m3/s and 42.61 m3/s are similar, meaning, this small variation is not very important. It is also highlighted that in stilling basin of both charts water levels are uniform. Tables 6 and 7 also show the values of the graphs of the figures for 5 important points: the entrance to the intake, the beginning of weir, at basin entrance, at basin exit and at breakwater exit.

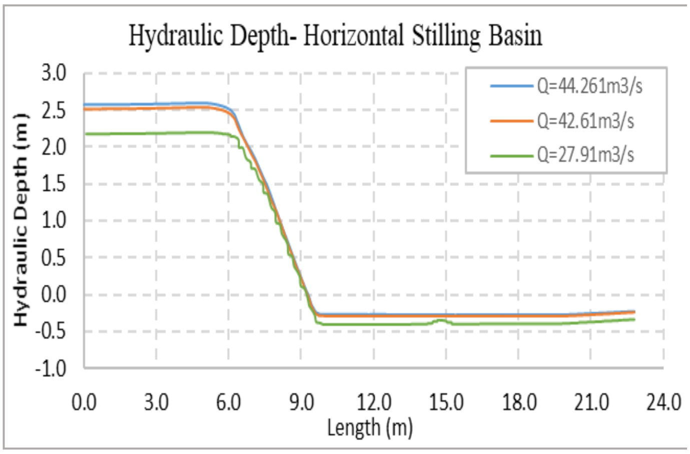

Figure 5. Longitudinal profile- Horizontal basin.

Table 6. Hydraulic depth values - Horizontal basin.

Hydraulic depth (m)			
Flows (m³/s)	**Q_{50} 44.26**	**Q_{MP} 42.61**	**Q_E 27.91**
Intake inlet	2.56	2.52	2.16
Weir start	2.58	2.55	2.17
Basin entrance	0.32	0.30	0.19
Basin exit	0.30	0.29	0.18
Breakwater exit	0.35	0.34	0.24

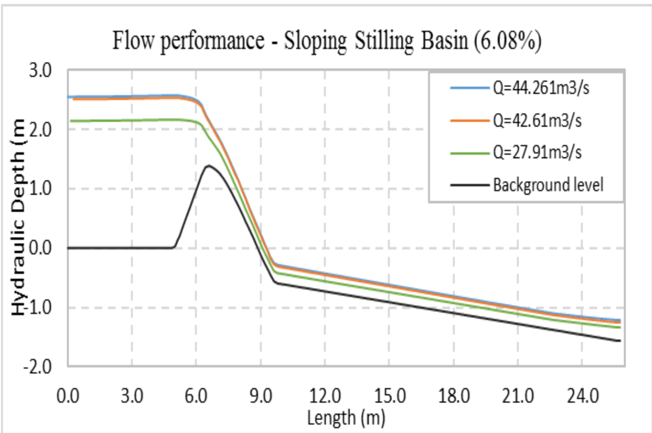

Figure 6. Longitudinal profile- 6.08% slope basin.

Table 7. Hydraulic depth values - 6.08% slope basin.

Hydraulic depth (m)			
Flows (m³/s)	**Q_{50} 44.26**	**Q_{MP} 42.61**	**Q_E 27.91**
Intake inlet	2.55	2.51	2.15
Weir start	2.57	2.54	2.16
Basin entrance	0.31	0.30	0.17
Basin exit	0.26	0.25	0.16
Breakwater exit	0.32	0.31	0.21

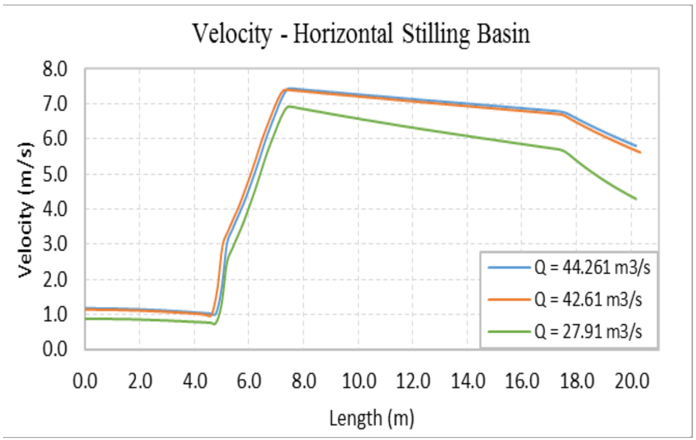

Figure 7. Velocity values in horizontal stilling basin.

Table 8. Velocity values - Horizontal basin.

Flows (m^3/s)	Q_{50} 44.26	Q_{MP} 42.61	Q_E 27.91
	Velocity (m/s)		
Intake inlet	1.18	1.16	0.89
Weir start	1.03	1.00	0.78
Basin entrance	7.15	7.11	6.29
Basin exit	6.79	6.71	5.74
Breakwater exit	5.74	4.23	4.23

Figures 7 and 8 show the velocity behaviours for both models and Tables 8 and 9 show the values at the 5 important points penalised. Behaviour for both the design and extraordinary maximum flow rate are very close, as flow rate only varies by 1.65 m3/s, with extraordinary maximum flow rate being lower than design flow rate. In the case of the average maximum flow rate, velocity values are lower than previous ones, however, it has same behaviour. Velocity gradually decreases until it reaches the breakwater where you see a further decrease.

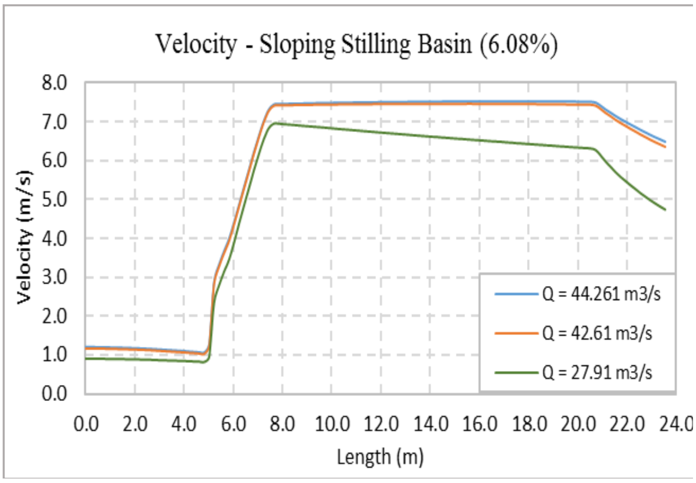

Figure 8. Velocity values in stilling basin with slope of 6.08%.

Table 9. Velocity values - 6.08% slope basin.

Flows (m^3/s)	Q_{50} 44.26	Q_{MP} 42.61	Q_E 27.91
	Velocity (m/s)		
Intake inlet	1.18	1.16	0.89
Weir start	1.03	1.02	0.81
Basin entrance	7.39	7.20	6.90
Basin exit	7.52	7.43	6.31
Breakwater exit	6.40	6.27	4.71

Figures 9 and 10 show values of energy for both stilling basins and the Tables 10 and 11 show the precise values for each point. Initial energy at the inlet is constant for flow rates, presenting a curve in the relief part. The energy values tend to decline along stilling basins, meaning that it loses energy as the section progresses. For stilling basin with a 6.08% slope, it can be observed a greater decrease in energy than in horizontal basin.

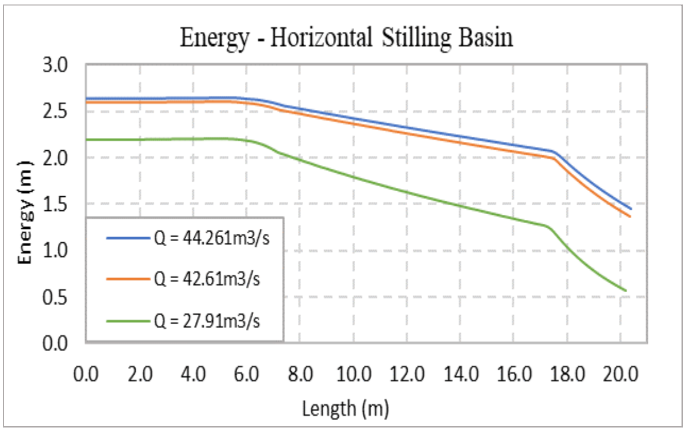

Figure 9. Energy values - Horizontal Stilling basin.

Table 10. Energy values - Horizontal basin.

	Energy (m)		
Flows (m^3/s)	**Q_{50} 44.26**	**Q_{MP} 42.61**	**Q_E 27.91**
Intake inlet	2.63	2.59	2.20
Weir start	2.64	2.60	2.21
Basin entrance	2.57	2.53	2.09
Basin exit	2.07	2.00	1.26
Breakwater exit	1.45	1.37	0.57

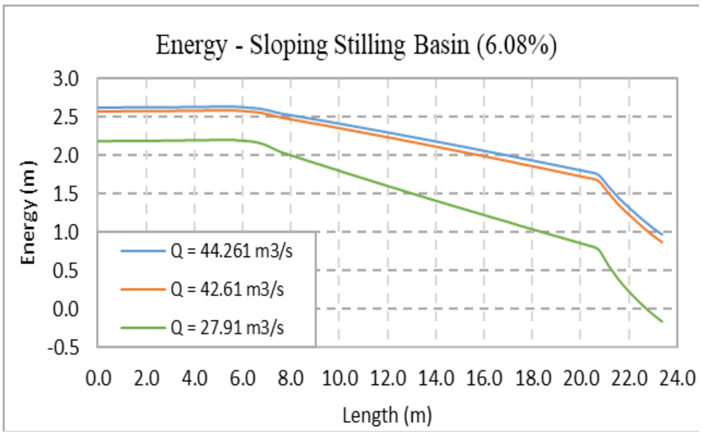

Figure 10. Energy values – 6.08% Stilling basin.

Table 11. Energy values - 6.08% slope basin.

	Energy (m)		
Flows (m^3/s)	**Q_{50} 44.26**	**Q_{MP} 42.61**	**Q_E 27.91**
Intake inlet	2.63	2.58	2.19
Weir start	2.64	2.59	2.21
Basin entrance	2.56	2.51	2.07
Basin exit	1.78	1.70	0.81
Breakwater exit	0.98	0.87	-0.16

This sensitivity analysis concludes that values of depth, velocity, and energy differ according to different flow rates with same trend, and the model is approved.

3.4. Comparison with design values

Stilling basin design is based on hydraulic jump behaviour. For these, conjugated depths were calculated y1: Flow depth of pre-jump, y2: Flow depth after jump. Y1 was found based on the data at barrage entrance. Contreras and Villegas [7] values were obtained considering the occurrence of the hydraulic jump applying the Kindsvater equation, with a 6.08 % slope, were modelled in IBER, which works with Saint Venant equations and the results shown in Table 12 were obtained.

Table 12. Comparison between Contreras-Villegas design and by IBER model.

	Contreras and Villegas Design	**IBER Model**
Flow depth of pre-jump (y_1)	0.69 m	0.31 m
Velocity at the stilling basin inlet (V_1)	6.42 m/s	7.39 m/s
Froude at stilling basin entrance (F_1)	2.47	3.62
Flow depth after jump (y_2)	2.63 m	0.26

A large difference can be seen between calculations and modelling causing uncertainty in the results of the IBER model. However, it must be considered that conditions for both are not the same because in empirical calculation width of the barrage is considered to be 10m and in the case of modelling the entire channel a width of 15 m was considered as well as the basin entrance. As the conditions are not the same it is expected that the results will vary, with this comparison, it is rescued that the design of water intake calculated empirically is not enough to the modelling, since in real conditions result could vary. 10

3.5. Additional proposals for stilling basin

Proposals includes sloping basins for: 1.52%, 3.04%, and 4.56% to see the variation in results as the slope increases. Design is based on Peterka's "Hydraulic Design of Stilling Basins and Energy Dissipators" [8]. Hydraulic jump components are found by using Kindsvater equation. The equation (1) [11] was applied for stilling basin calculations, also used by Contreras and Villegas [7], with this formula y_2 is obtained, coefficient K is used according to Pardo, Wong and Cabrera as in equation (2).

$$\frac{y_2}{y_1} = \frac{1}{2\times\cos\theta}\left(\sqrt{\frac{8.{F_{r1}}^2.(\cos\theta)^3}{1-2.K.\tan\theta}+1}-1\right) \tag{1}$$

$$K = 4.075 - 27.56249.S_0 + 113.0682.{S_0}^2 - 182.9947.{S_0}^3 \tag{2}$$

Y_2 is calculated based on y1 and the Froude number at hydraulic jump beginning. Length of the pool is determined using the U.S. Bureau of Reclamation graph "Length of the jump in terms of conjugate depth, Ds (Basin V, Case D)" [8]. Table 13 shows values obtained for three proposals.

Table 13. Proposal results.

Measures for proposed stilling basins			
Measures	**1.52 %**	**3.04%**	**4.56%**
Tilt angle	0.87°	1.74°	2.61°
Shape coefficient	3.68	3.34	3.04
y_2 (m)	2.24	2.38	2.51
Length (m)	11.10	11.85	12.51

With length found and inclination angle, stilling basin is modelled for each proposal, results and comparison are shown in the following section.

4. Results Analysis

This section compares how slope variation influences flow of the stilling basin for hydraulic depth, velocity, Froude, and energy parameters. Hydraulic depth results are show in Table 14. Differences between 5 slopes vary by 0.01 m and 0.02 m between them, so this parameter is not very significant in variation of the slope of stilling basin.

Table 14. Stilling basin's hydraulic depth (y1) with 5 different slopes.

	0%	1.52%	3.04%	4.56%	6.08%
Basin entrance	0.32	0.31	0.32	0.32	0.31
Basin exit	0.30	0.30	0.28	0.28	0.26
Hydraulic depth variation	0.02	0.01	0.04	0.04	0.05

Concerning velocity values in figure 11 it is observed that higher the slope higher the velocity of the flow at stilling basin ending, the 5 slopes have the same trend. Results at the basin inlet are the same for all of them since the same discharge of 44.261 m3/s for all 5 models, this value is 1.03 m/s. In figure 11, we observe that when slope increases to 1.52%, velocity increases by 0.04 m/s which is not a very significant value: in percentage is 1.17%. When slope increases to 3.04% velocity increases by 5% compared to previous slope value. For slope value of 4.56% velocity increases by 1.2% and finally for 6.08% slope, velocity increases by 3.9%. With these results it is seen that when the slope increases to 1.52% the velocity values do not increase significantly, but when the slope increases to 3.04% the velocity results significantly influence. As the natural flow of the river has a velocity of 6.65m/s approximately the result resembles the horizontal slope.

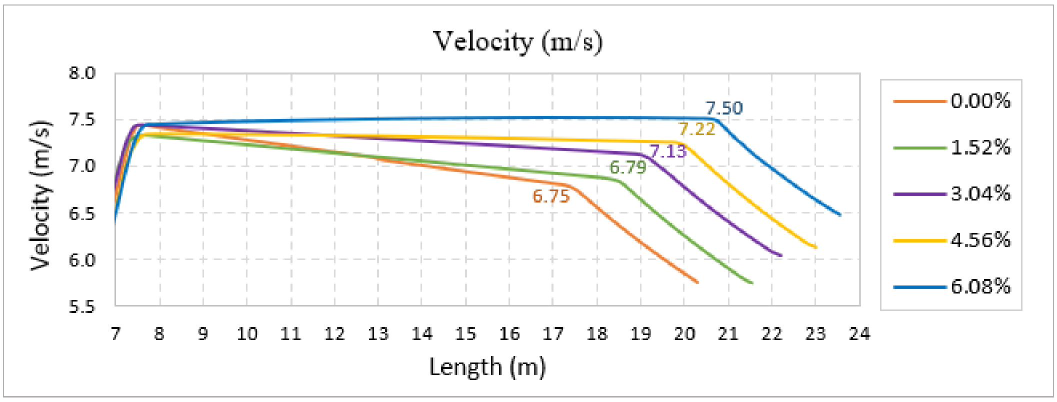

Figure 11. Velocity for 5 different slopes.

Similarly, the graphs for Froude values are displayed in figure 12. For this case, the Froude values at the basin output increase as the slope increases. The results in this case at the output vary from horizontal slope 3.93, 4.01, 4.25, 4.38 and 4.61. In this case it is also seen that the variation of the values when the slope increases to 1.52% and 4.56% the change from the previous slope is 0.08 and 0.13 respectively, the first case does not affect too much and in the second case does, however, when the slope increases to 3.04% and 6.08% the Froude increases by 0.24 and 0.23 compared to its previous slope, it is observed that in these variations that the Froude values does influence. In other words, to have a greater variation in Froude, the slope must increase by 3.04%. Concerning the value most similar to the natural flow of river of the case under study, which has an average of 4.12, is the slope of 3.04%.

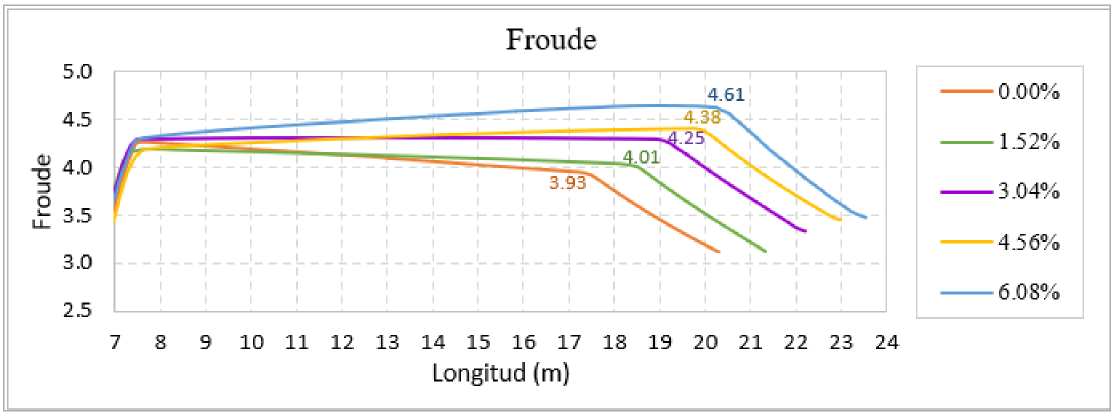

Figure 12. Froude values for the 5 slopes.

Energy variation results for different slopes are shown graphically in figure 13. Efficiency of a stilling basin is measured by amount of energy expelled. More energy its expelled, the more efficient it is. Therefore, energy at the basin end of each stilling basin has been compared. The values in this case are shown in Table 15.

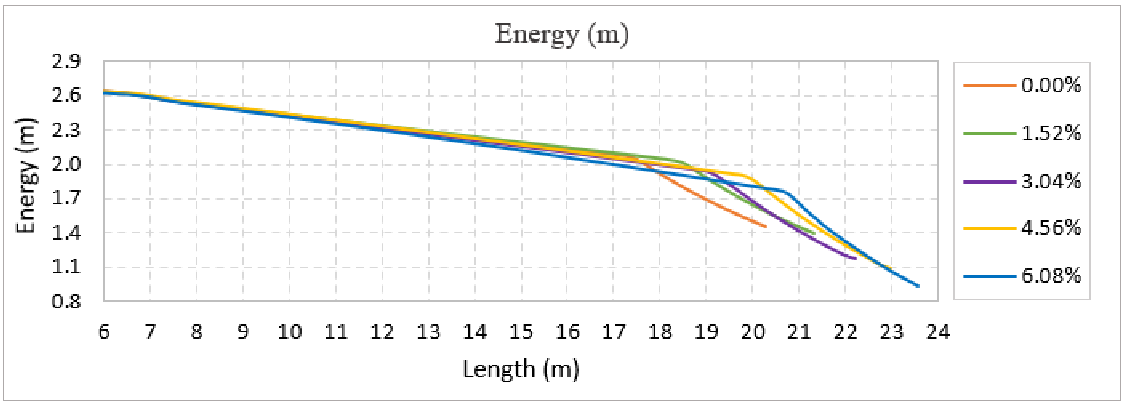

Figure 13. Energy values for the 5 slopes.

Table 15. Energy values for 5 slopes.

Energy (m)					
	Percentage of slope				
	0%	**1.52%**	**3.04%**	**4.56%**	**6.08%**
Spillway entrance	2.64	2.64	2.64	2.64	2.65
Basin entrance	2.57	2.56	2.57	2.57	2.56
Basin exit	2.07	2.01	1.90	1.87	1.76
Lost energy	0.57	0.63	0.74	0.77	0.89

Concerning the horizontal slope stilling basin, the 6.08% stilling basin is more efficient in 56%. The energy loss of the 4.56% stilling basin relative to the horizontal is 36% more. The energy loss of the 3.04% stilling basin relative to the horizontal is 30% more. The energy loss of the 1.52% stilling basin relative to the horizontal is 11% more. It is observed with the results that the stilling basin with a 6.08% slope equal to the average slope of the San Pedro River is more efficient than the other stilling basins with proposed slopes.

5. Conclusions

From the five different slopes modelled, it was shown that variation in hydraulic depth parameter is not very significant between them as they vary between 1 and 2 cm. These are also low values, so it is necessary to place accessories in the stilling basin to raise the water level in order to connect it with the natural level of the river seen in the case study. Also, according to analysis for results variation of simulated slopes of basin, it was found: with higher slope, higher output velocity, lower y2, higher Froude number, and longer length of the basin.

Stilling basin with a slope of 3.04%, is suitable for San Pedro river. It has an energy loss of 30% more than the horizontal buffer basin. An acceptable and controllable output velocity lower that of the buffer basin of 6.08% and a Froude number that resembles that of the river of 4.12.

IBER software has advantage of being a fast, robust, and free program. It showed that it not only models' geometry on a large scale but can model hydraulic structures 25 meters long like the one presented in this research. On the other hand, IBER software has disadvantages in the fact that some flow conditions cannot be observed as the turbulence that forms and it cannot add three-dimensional elements, since it does not model vertical elements.

It is suggested to complement design of stilling basin with sloping bottom with other dissipation elements such as stilling dice to reduce its length, as well as a modelling of the structure with the river to appreciate the splice of water levels.

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