Experimental Investigations on Sediments Removal Around Dam Hydropower Intake by Scouring

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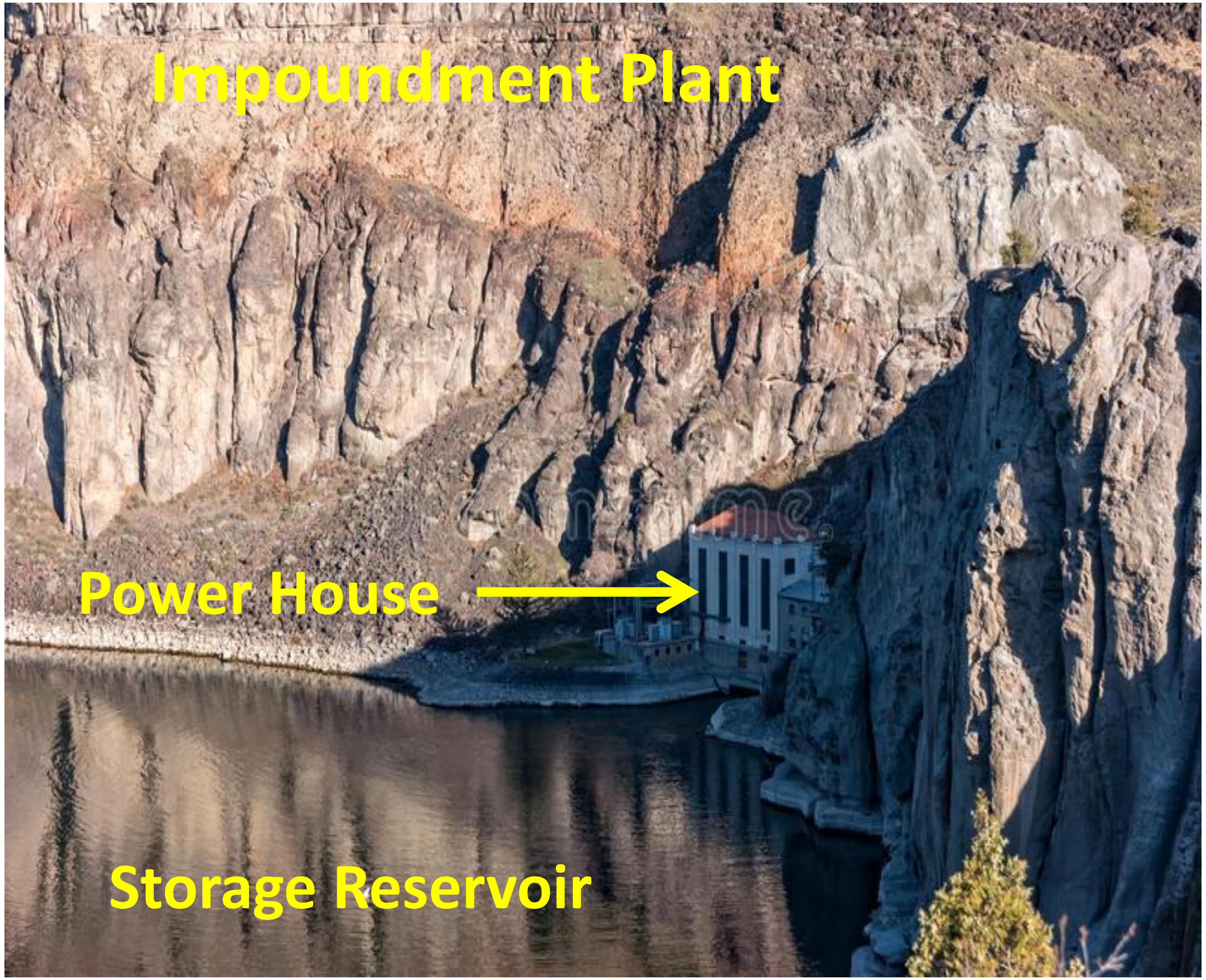
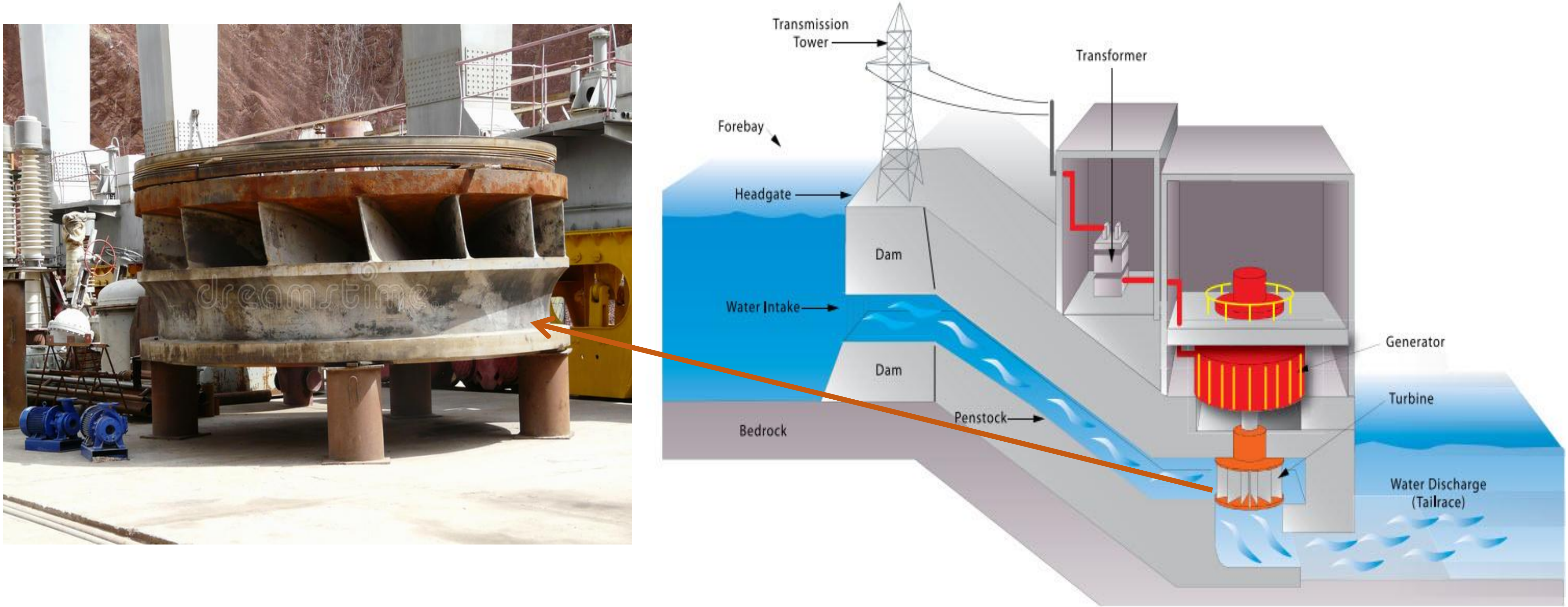
Problem Statement

Reservoir sedimentation endangered sustainability of hydropower plants such as impoundment and run off the river plants. Sedimentation of reservoirs is causing various problems such as increasing flood risk of infrastructures around reservoirs, and decreasing the active water capacity of reservoir leading to loss of power generation.

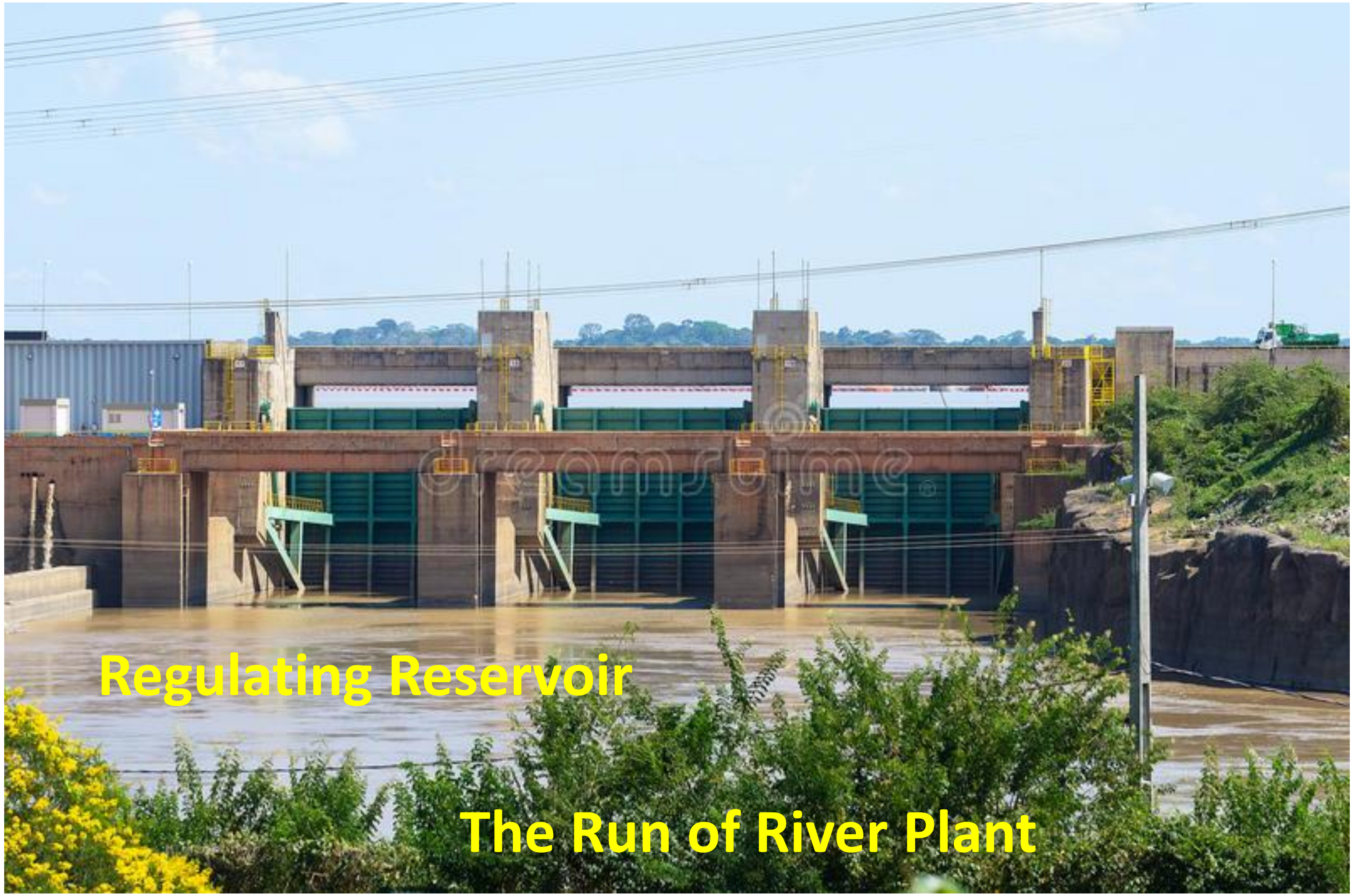




Abrasion of the turbine blades by sediment increased maintenance costs and reduce production

Considering the differences of two major types of hydropower plants, which are storage type and regulating type (Run of the river).

It is more important to manage sedimentation in regulating reservoirs than storage ones. Because sedimentation in regulating reservoir is more dominant than the storage ones.



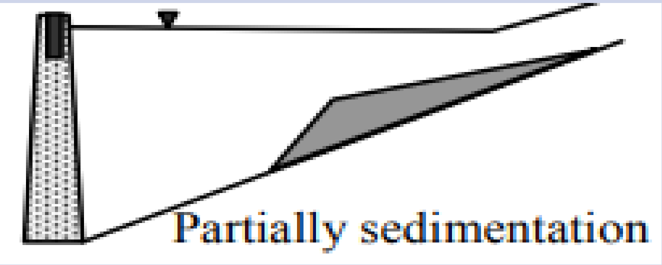
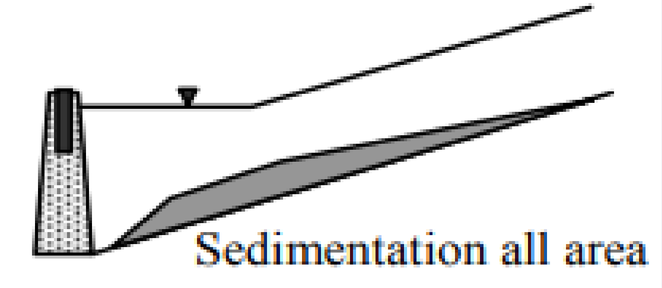
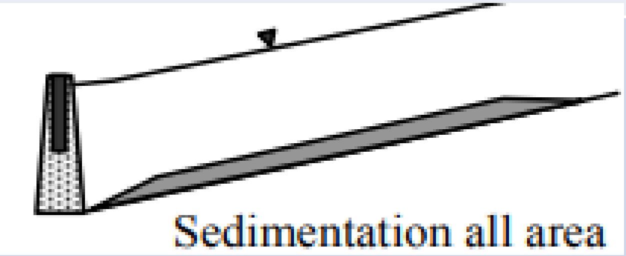
- Okumura and Sumi (2012), 95 reservoirs of hydropower plants in Japan were influenced by increasing sedimentation and flood risk.

- Boroujeni (2012) estimated the volume of sediment accumulations in Dez Dam hydropower reservoir, Iran for 50 years and it was reported as 840 million cubic meters (million m^3).

- Kamarudin et al. (2018) highlighted the sedimentation problem in the lake of Kenyir dam, Terenggana, Malaysia which was affected the production of the Sultan Muhmud hydroelectric power station.

- Reisenbüchler et al. (2020) warned that the run of river hydropower plant located in the Saalach River in southeastern Germany was subjected to sedimentation.

Table 1. Effective sediment management measures for 3 regulating reservoir types (Okumura and Sumi, 012)

Reservoir Type	Shape of Water Level and Condition of Sedimentation	Effective Sediment Management Measures
Lake		1. Drawdown and Lowering the Level of Dead Storage 2. Sediment by pass
Intermediate		1. Drawdown and Lowering the Level of Dead Storage 2. Passage of the Sedimentation through the gate
River		1. Draw-down Operation During flood 2. Passage of Sedimentation Through the Gate

The frequent removal of sediment accumulation from reservoirs by dredging requires interruption of power generation and conveyance of the fine sediments from upstream to downstream through hydraulic structures is a sustainable solution or an effective sediment management measure as recommended by Okumura and Sumi (2012) . Ota et al. (2017a) proposed a numerical model based on the sediment continuity equation and sediment entrainment volume from a scour hole of uniform sediment upstream of a slit weir.

Objective

The main objective of the present study is to investigate the effectiveness of using slit weir for sediment removal from reservoirs. The studied variables were sediment nonuniformity, slit weir dimensions, weir notch location (slit location), and flow intensity.

Materials and Methods

A series of experimental investigations were conducted in a glass-sided tilting flume 0.30 m wide, 12 m long, and 0.30 m deep. The slit weirs used in the experiments were made up from Plexiglas with a thickness of 6mm. The working section was with a length of 2m and a width of 30cm (same width of the flume). The section was filled with sediment up to a depth of 11cm.

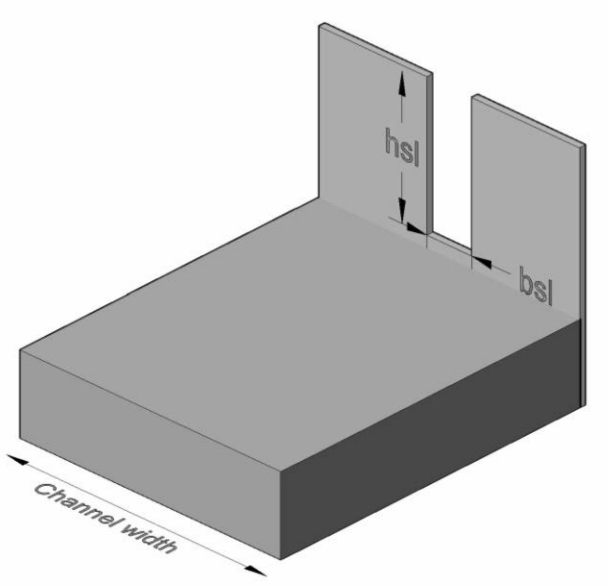


***Figure 1(a)*. The working section before scouring**

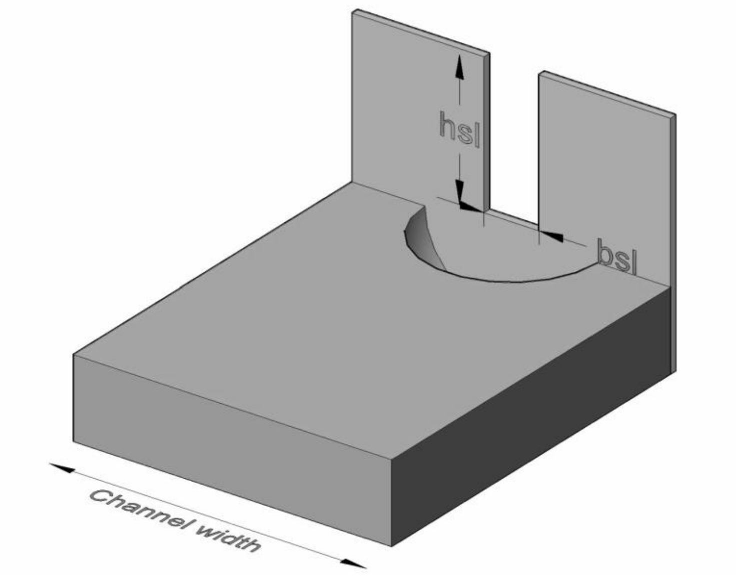


***Figure 1(b)*. The formation of scour hole (weir notch in the center)**

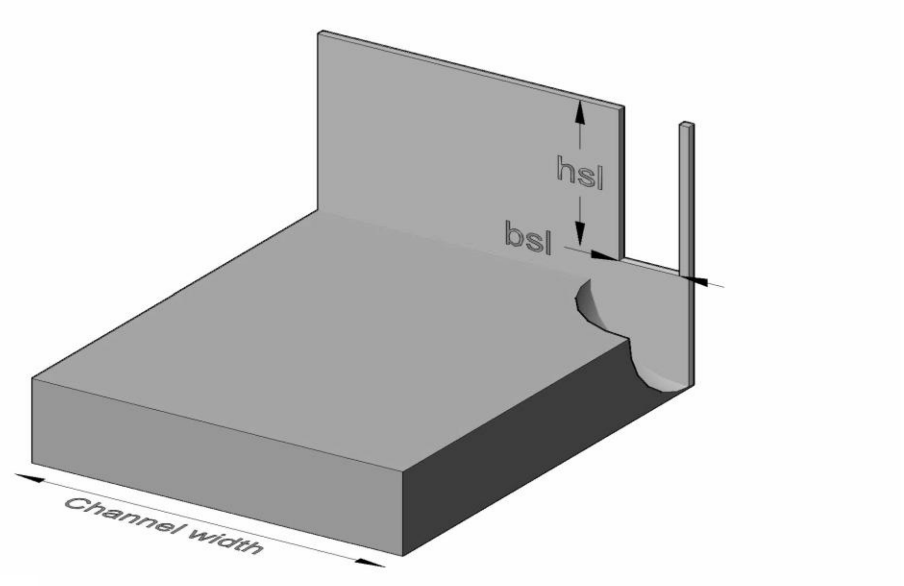


***Figure 1(b)*. The formation of scour hole (weir notch in the center)**

Figure 1

In nature and according to Subramanya (2015), the sediments have nonuniform size distribution and it is usual to take the median size, d_{50} as a representative size of sediments. So, two types of nonuniform sand were used in the working section of the flume and these types were sediments with median size, d_{50} =0.30 mm and sediments with d_{50} =0.70mm. In addition, the values of geometric standard deviation, σ_g for the first type and the second type of the sediments were found to be 1.58 and 1.60 respectively. Figures 2 and 3 show the graduation curves for the sediments.

All experiments were carried out for 300 minutes under clear water scour conditions which usually exist when the flow intensity (mean approach velocity,v/critical velocity, v_c<1). The clear water scour conditions exist for both uniform and nonuniform sediments when flow intensity, $v/v_c<1$ or $[v-(v_a-v_c)]/v_c<1$ respectively. In this study, the maximum value of the flow intensity was 0.8. However, v_a is called by (Melville and Coleman (2000) armor peak velocity.

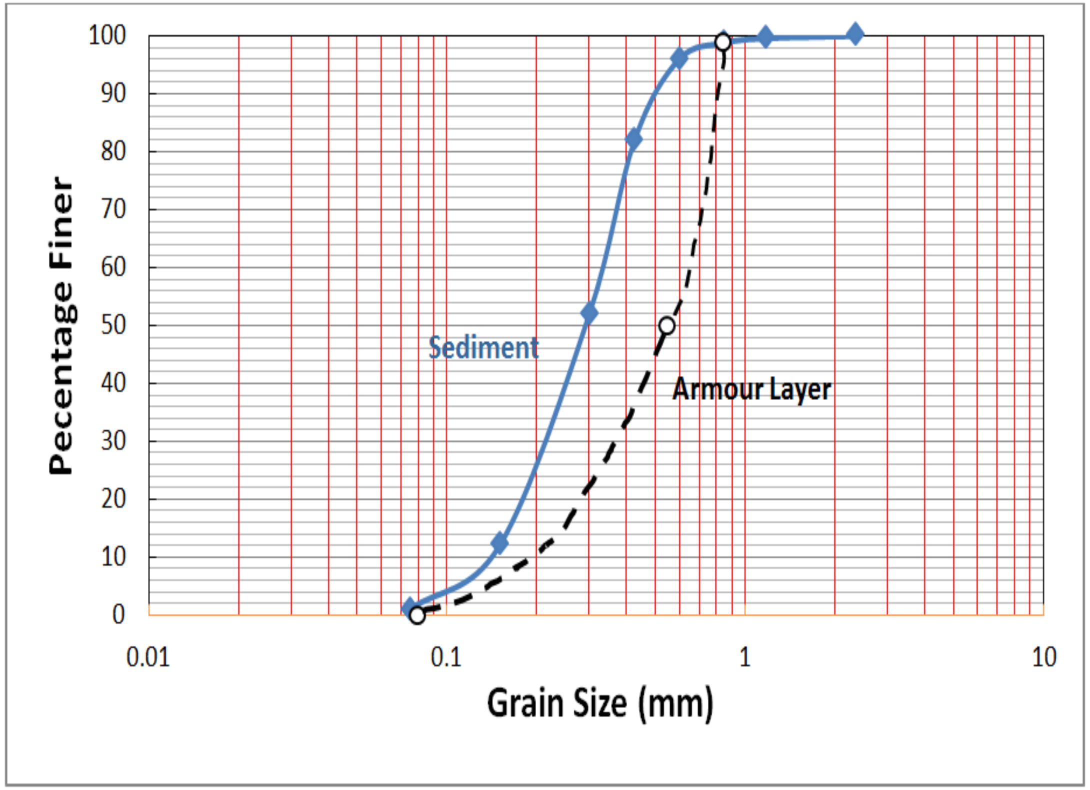


Figure 2. Grain size distribution curves for the sediments (d_{50} =0.30mm) and armour layer

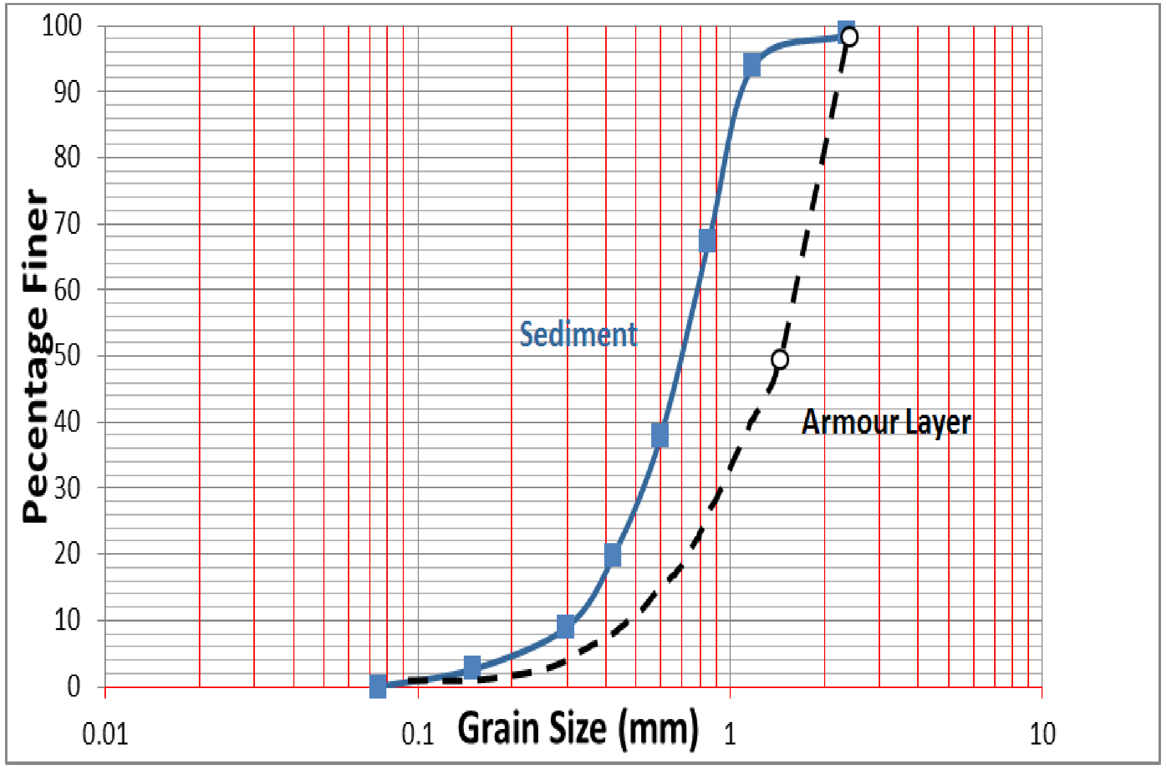


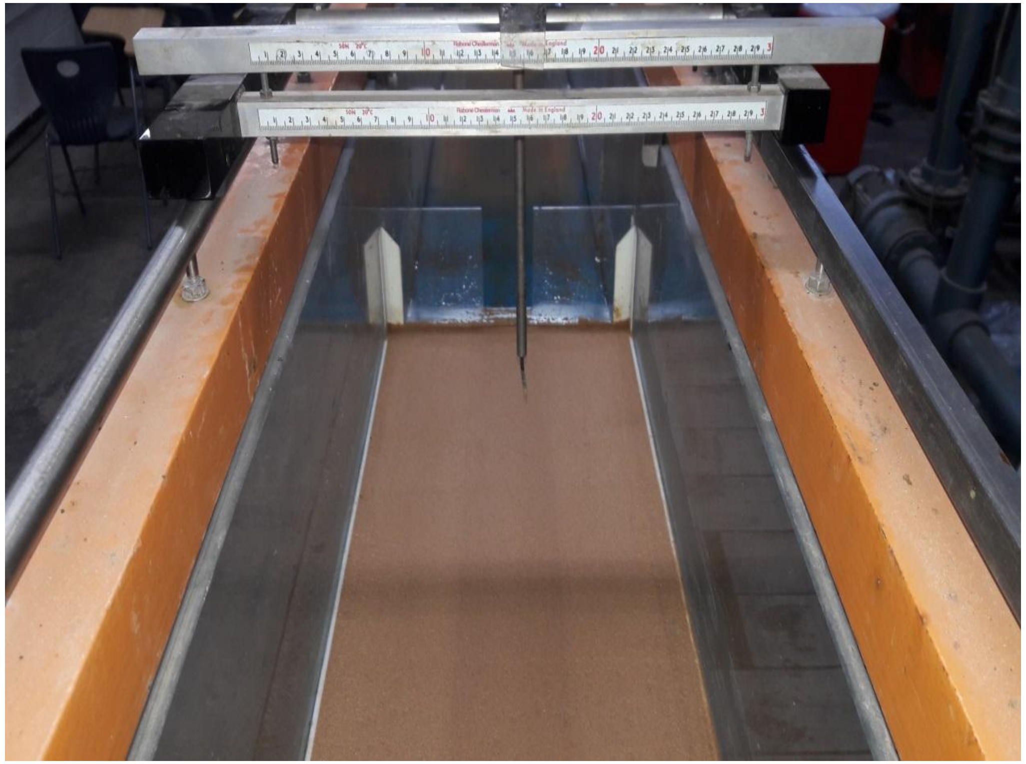
Figure 3. Grain size distribution curves for the sediments (d_{50} =0.70mm) and armour layer

The slit weirs used in the experiments were made up from Plexiglas with a thickness of 6mm. In this study, two locations for the slit of weirs were tested. Table 2 shows the dimensions and locations of the slit weirs used in this study.

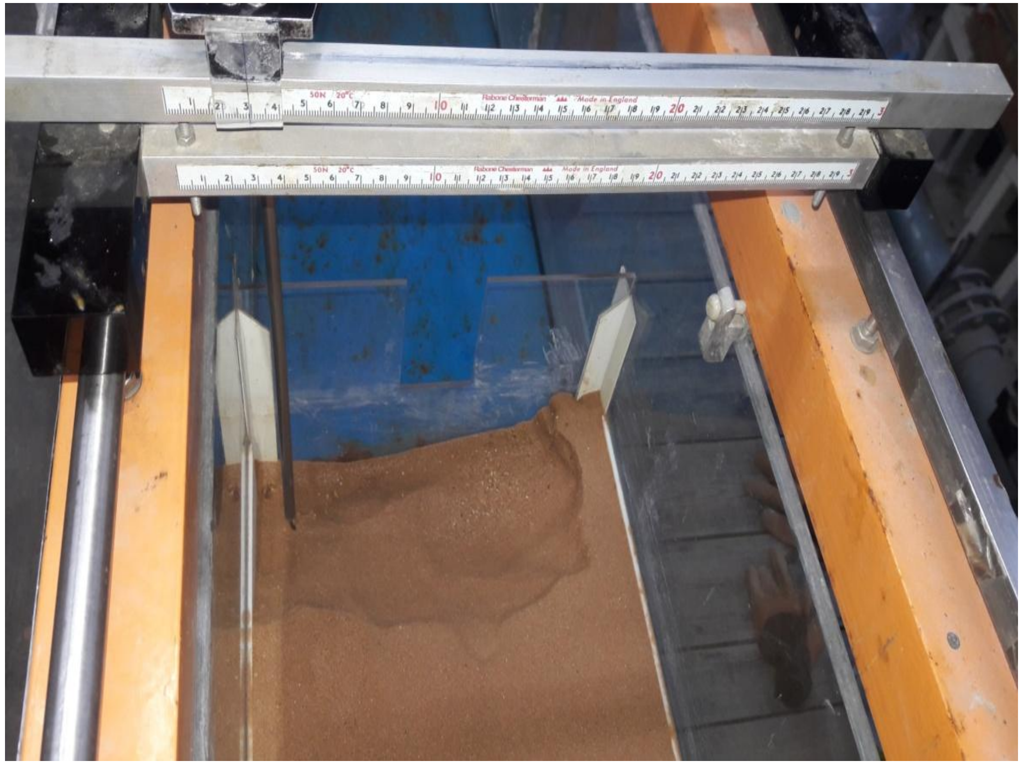
Table 2. Dimensions and locations of the slit weirs

Slit location	Dimensions (h_{sl} x b_{sl})	z^*
Center	11x6 cm	0cm
Center	10x6 cm	1cm
Center	9x6 cm	2cm
Center	8x6 cm	3cm
Center	7x6 cm	4cm
Side	10x6cm	1cm

z^* is the distance in cm between the crest of the weir and the bed of the working section before the commencement of the experiments



a. Before the experiment



b. After the experiment

Figure 4

Results and Discussion

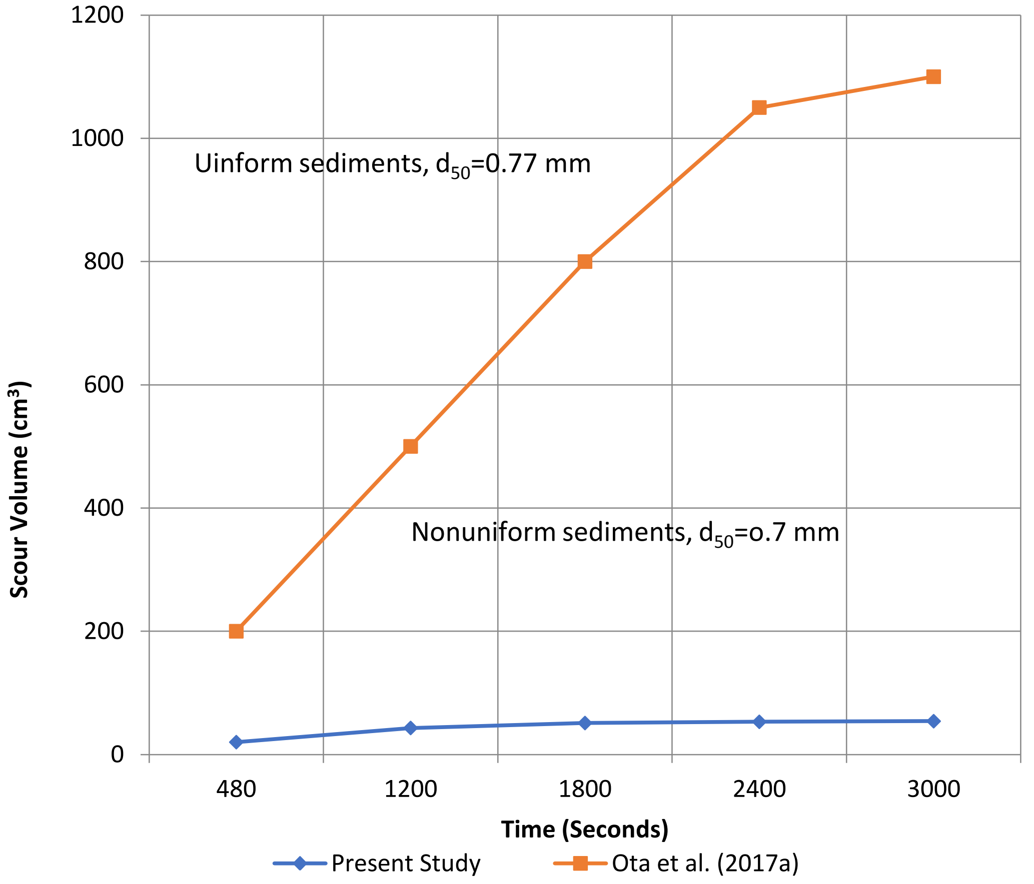


Figure 5. Impact of sediment nonuniformity on scour volume

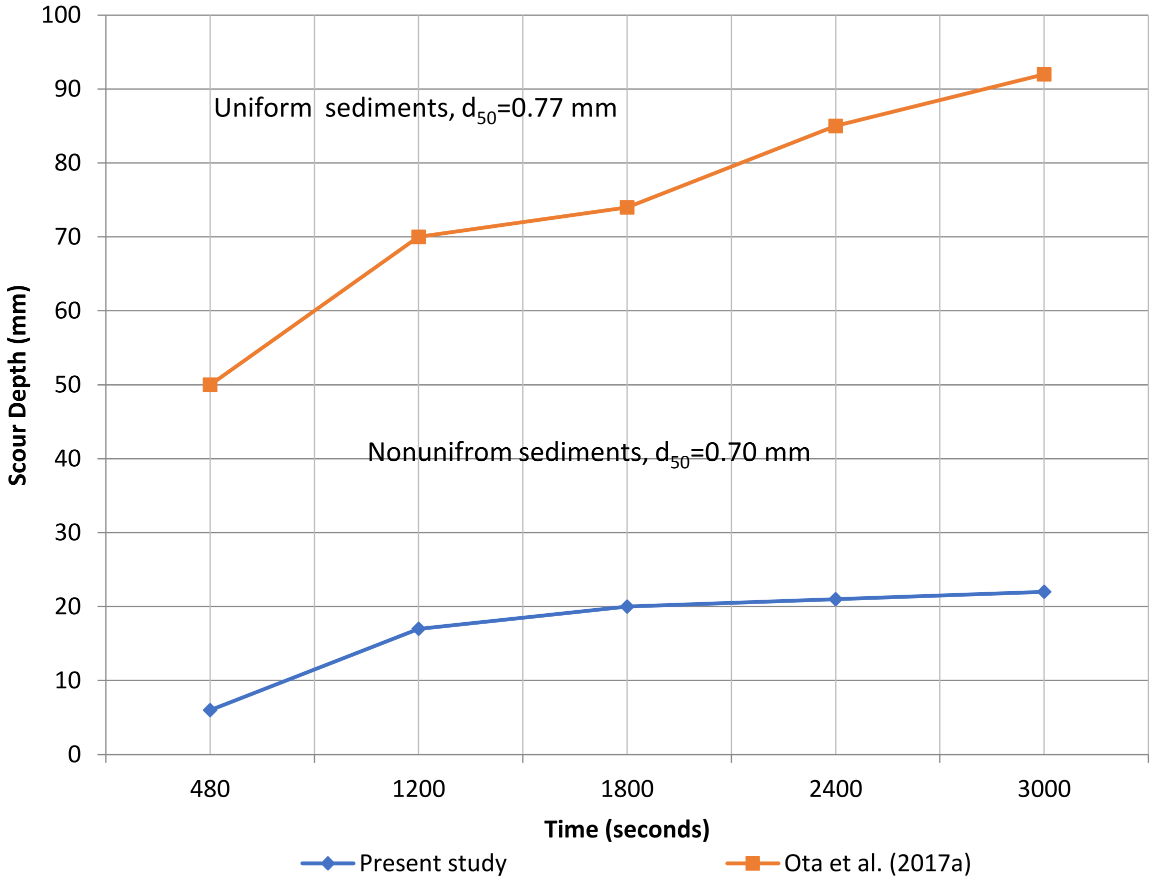


Figure 6. Impact of sediment nonuniformity on scour depth

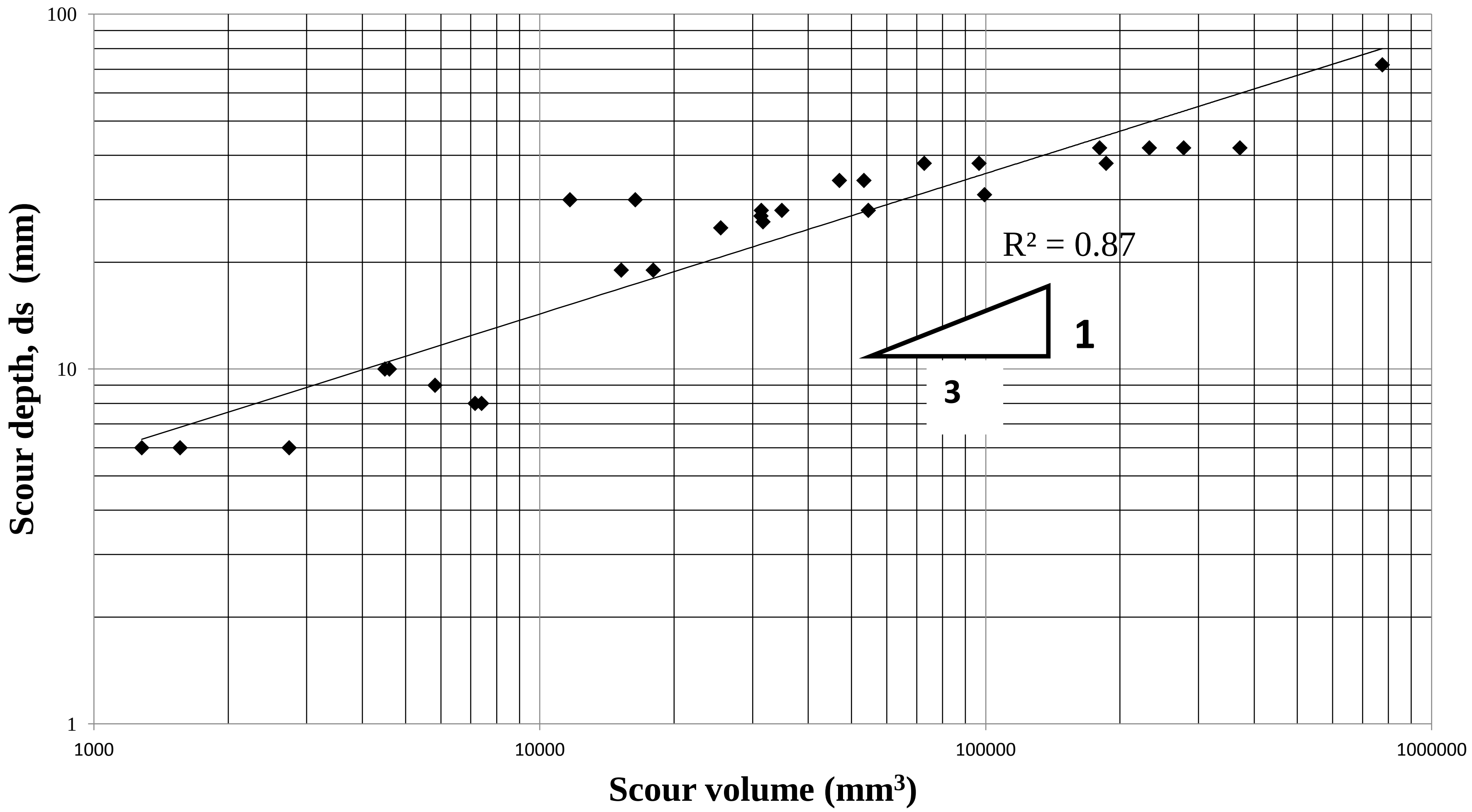


Figure 7. Relationship between maximum scour depth and scour volume for nonuniform sediments

The value of *ME* was calculated and found to be 0.86 which confirms the efficiency of Equation [1]. In addition, Ota et al. (2017a) recommend applying Equation [1] for both model and prototype.

$$d_s/(V_s)^{1/3}=0.39(b_{sl}/B)^{-0.383} \qquad [1]$$

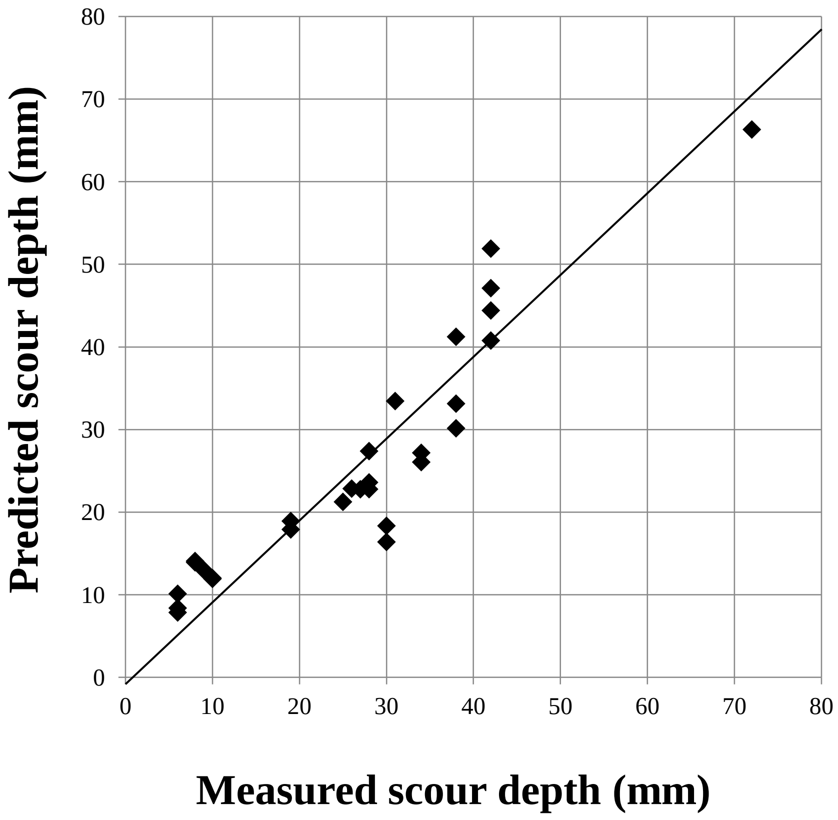


Figure 8. Validation of Equation [1]

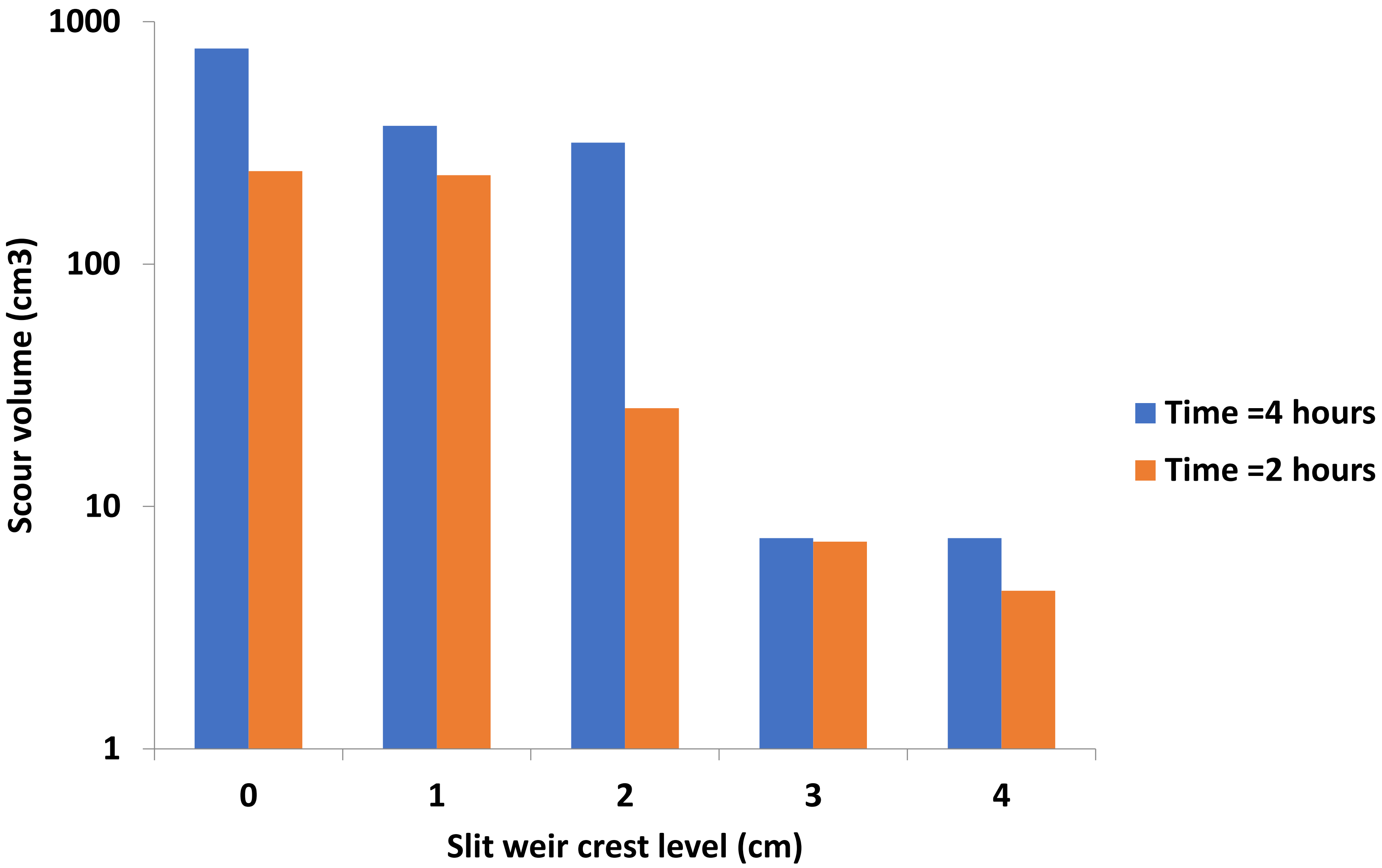


Figure 9. Variation of scour volume with slit weir crest level for a flow rate of 8 l/s and sediment size of 0.30 mm

Slit weir location at the center

Slit weir location at the side

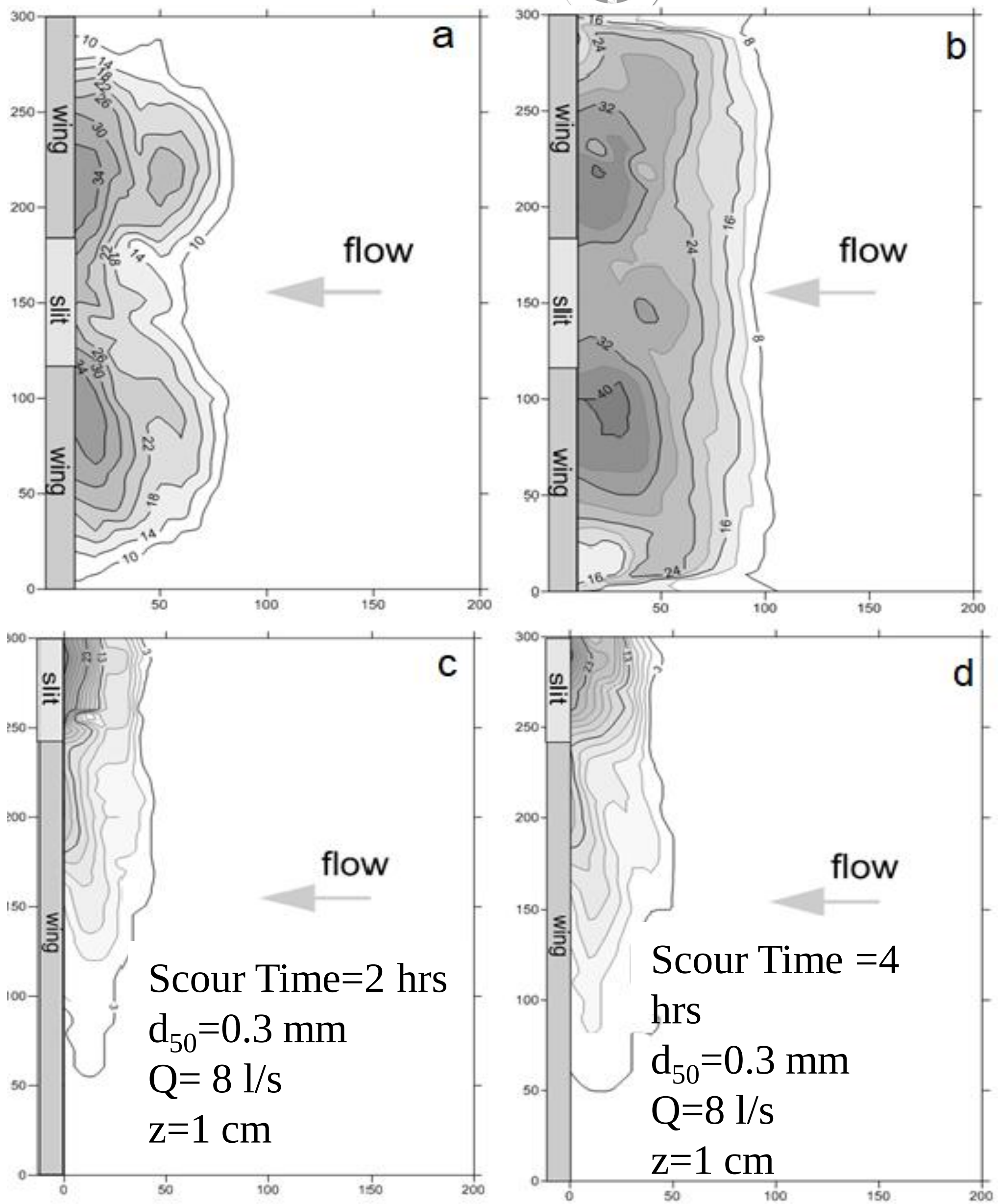


Figure 10. Contours of scour holes for different weir notch locations

Conclusions

The experimental results revealed the following:

- The scour volume was significantly affected when the level and location of the slit of the weir. For same flow conditions, slit level from the mobile bed, z, and sediment median size, d_{50}, the scour volume was much higher when the slit of the weir was located at the center compared with that located at the side. For Q=8 l/s, z=1 cm and d_{50}=0.30mm, the scour volume when the slit located at the center was 14 folds greater than that occurred when the slit was located at the side. The strength of the formed vortices is affected by slit location which eventually affects the size of scour hole.

- For a discharge of 8 l/s and when the median size of sediments in the working section, d_{50} was changed from 0.30 mm to 0.70mm, the scour volume upstream of the weir with the slit at the center was reduced by 22 folds.

- The temporal variation of scour volume was monitored and compared with the published data of uniform sediments (d_{50}=0.77mm) and same flow conditions. Comparison showed that the scour volume and maximum scour depth occurred in uniform sediments were 20 folds and 4 folds greater than that occurred in nonunifrom sediments in respectively.

- The experiments proofed that the slit weir can be used to cause scouring at accumulations of sediments at upstream and near the locations of hydropower intake particularly in the regulating reservoirs.

Thank you