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Simulation of interaction of side weir overflows with bed-load transport and bed morphology in a channel (SSIIM2.0)

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To describe the complexity of flows accurately around side spillways, a 3D numerical flow model has been tested. In this study 3D numerical model SSIIM2.0 is used to simulate unsteady flows in side spillways in a schematic test channel. Side channel spillways are one of the types of outlet works at dams with wide applications in irrigation, drainage systems, in water and wastewater facilities. Overflow side, known as cross overflow and overflow sections as a free overflow and flow diversion devices are used in hydraulic engineering. They are made in the side channels or rivers to overflow part of discharge's crown at the top of the main level. When accidental drop of water happen, sediment transport capacity in the main channel of investment and deposits alluvium for deposition in downstream reduced. Reduce levels, provides back water, additional expansion and contraction. So the height of the energy loss of the side spillway and overflow discharge increases. Design discharge to offset increases in the flow of sediment transport. The present confrontation with the overflow stream bed morphology and bed load in a regular channel experiments conducted has not been studied. Results showed that increase in spillway length turbulence in the flow is reduced and morphological changes decrease. Intensity of erosion and sedimentation over time has been increased, in the early minutes of calculations, the rate changes over time in bed was significantly reduced. The results demonstrate the ability of numerical models SSIIM2.0, to simulate the flow in the side spillway.

Key words: Overflow side, cross flow, bed morphology, sediment deposited, side spillway, 3D CFD model, $k-\varepsilon$ turbulence model.

INTRODUCTION

Considering the widespread destruction of the side channels offset overflows and floods that has been occurred, correction the method is necessary. So the design of such structures must be done correctly to reduce construction cost, repair and the annual reconstruction plans flood control. Construction significantly would reduce, If design of spillways in diversion of water spreading systems done according to engineering principles. Degradation that has occurred in the channel system of flood peripherals overflows or hydraulic conductivity of this system is the main motivation for this scheme. Using a mathematical model of the experimental model designed to achieve a basis consistent with the circumstances of this kind of structures can also reduce costs, increase correct understanding of its performance and increased design

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accuracy for each type of geometry.

Forecast during the transfer process within the main channel and side weir can be both experimental and computational research. Nowadays, numerical methods in computer calculations are important as an efficient tool in the design and reducing construction and engineering costs. In this study numerical model, SSIIM2.0, was used to simulate side spillway and sedimentation in the channel.

Fluid-sediment interactions control river channel forms and processes. Analysis of spatial hydraulic patterns and the resulting boundary shear stress are required to aid understanding of river system behavior. In this paper, the hydraulic processes active in a side channel spillways simulated using a three-dimensional computational fluid dynamics (SSIIM2.0) model.

Methods employed for the prescription of model boundary conditions are outlined. Model calculations are assessed using comparisons with field observations acquired over a range of flows. Simulations are then used to illustrate flow structures.

Side weirs, also known as a lateral weirs, and overflow dams are free overflow regulation and diversion devices commonly encountered in hydraulic engineering. They are set into the side of a channel or river allowing spilling a part of the discharge over their crest when the surface of the flow in the main-channel exceeds a certain level.

The lateral loss of water is reducing the sediment transport capacity in the main-channel yielding to aggradations and the formation of a local sediment deposit in the downstream weir alignment.

The reduced cross section generates backwater effects and additional contraction and expansion losses. As a consequence, the head over the side weir rises and the side overflow discharge as well. The design discharge to be diverted over the weir is increased by this flow-sediment transport interaction.

Since the interaction of side overflow with bed-load and bed morphology in a channel has not been studied so far, systematic tests have been performed.

Talebbeydokhti et al. (2006) stated that resistance to flow is an important and primary parameter in the determination of water surface elevation. A variety of bed forms, especially dunes, have a sensible effect on total roughness. Because of the complexity of bed form development, previous methods differ drastically from each other in predicting dune bed forms. In this paper, laboratory experiments were conducted to investigate the geometry of dunes in a sand-bed channel and its influence on total channel resistance. The experiments were performed in a flume in the hydraulic laboratory of Shiraz University using sand particles. Simple relations were sought for dune dimensions via some dimensional parameters, and previous methods were compared to each other in light of this new data. Thus, a new boundary condition has been introduced which has always been a free overall in the previous investigations. The effective crest length has been taken into account introducing a correction factor for the true crest length. The main-channel geometry in experiments restricted to subcritical flow has been rectangular and the weirs crests have been sharp (7 experiments) and broad crested (15 experiments). The discharge coefficient was assumed to be a function of the approach Froude number (Fr_1). For the broad crested weir, an empirical being a function of $y1-\omega D$ and crest width was added to the c_D-relation. The value $y1-\omega D$ was invariably maintained greater than 10.00 cm to eliminate effects of viscosity and surface tension thatmight be important at small heads. With respect to the constant specific energy approach, a different between the up- and downstream weir corner of less than 2% has been observed. Thus, this assumption has been concluded to be reasonable. The investigations resulted in a design procedure to determine the discharge to be passed into a branch channel.

Imanshoar et al. (2012) stated that subsurface erosion in river banks and its details, in spite of its occurrence in various parts of the world has rarely been paid attention to by researchers. In this paper, quantitative concept of the subsurface bank erosion has been investigated for vertical banks. Vertical banks were simulated experimentally by considering a sandy erodible layer overlaid by clayey one under uniformly distributed constant overhead pressure. Results of the experiments indicated that rate of sandy layer erosion is decreased by an increase in overburden; likewise, substituting 20% of coarse (3.5 mm) sand layer bed material by fine material (1.4 mm) may lead to a decrease in erosion rate by one-third. This signifies the importance of the bed material composition effect on sandy layers erosion due to subsurface erosion in river banks.

Yalin and da Silva (2001) chose the dimensionless chezy friction factor (c) to establish a relation for the grain roughness. The main input parameters are the grain size Renlds number (Re*) and the relative flow depth (y/d). The resistance due to form roughness is expressed in terms of the bed form length and steepness.

In addition an experimental and numerical study investigating the interaction of a side overflow with a mobile bed has been performed at the libratory of Hydraulic Constructions (LCH) by Teiller (2000).

Willey et al. (2010) researched that a series of relatively small floods caused extensive rock erosion, approximately 5000 m^3, in the unlined section of the spillway channel at Googong Dam. A range of protective remedial works were installed during the 1980s with varying success. The most recent phase of work commenced in 2006 with a review of the spillway's performance, assessment of future erosion potential and a comparison of remedial works options. The detailed design was developed for the preferred option, comprising the retro-fitting of a concrete-lined chute, the raising and extension of the spillway chute walls and strengthening of other existing components. Construction is currently underway by the Bulk water Alliance and is due for completion in late 2010. This paper will present details of the history of this project including the initial assessment, review of rock erosion potential, options comparison and the detailed design.

Chiew (1991) stated that none of the classification diagrams refer to non-uniform bed material. For this reason, a classification method for bed features in non-uniform sediments has been proposed.

Interaction between surface and tectonic processes plays a key role in the structural evolution, kinematics, and exhumation of rocks in orogenic wedges. The deformation patterns observed in analog models show that strain partitioning has a strong impact on the vertical component of displacement of tectonic units, which in return favors erosion in domains of important uplift. Partitioning is controlled by tectonic processes and by climate-dependent surface processes, including erosion and sedimentation. The effects of partitioning include localization of deformed domains, exhumation above areas of deep underplating, and steady-state maintenance of wedges for long time periods. Simple models illustrate well how the morphostructural evolution of mountain belts is determined by these complex interactions (Malavieille, 2009).

Resuming, the literature review indicates that at the current stage of research lateral overflow on fixed bed conditions is well studied. The same accounts for expressions referring to the side weir discharge coefficient, sediment transport and bed morphology. Almost no investigations deal with the interaction of lateral overflow, sediment transport and bed morphology as a combined problem and no integral approach relating them to each other have been developed yet.

Numerical model description

The numerical model used in this study is the CFD code called SSIIM (Olsen, 2002). SSIIM2.0 is an abbreviation for Sediment Simulation in Intakes with Multiblock option. It solves the Reynolds-averaged Navier-Stokes equations with the two equation k-e turbulence closure in three dimensions to compute the water flow using the finite volume approach as discretisation method. SSIIM is based on the solution of the Navier-Stokes equations, with the k-e model.

This gives the water velocity and turbulence field which is used for solving the convection-diffusion equation for the sediment concentration. The model simulates water and sediment movement in a complex three-dimensional geometry. The model has a graphical user interface with pre and post processors. The program uses a standard graphical user interface for OS/2 and runs only on this operating system.

This paper shows several examples where the program has been used. The initial motivation for making SSIIM2.0 was the limited possibilities of determining the flow of finer sediment particles in a complex geometry.

Equations governing this phenomenon

Bed load and suspended load sediment transport is usually divided into two groups. Suspended load can be determined by the equation (Convection-diffusion) for sediment concentration (C). Generally transport equation for sediment concentrations case is according to the Equation 1.

$$\frac{\partial c}{\partial t} + U_i \frac{\partial c}{\partial x_i} + W \frac{\partial c}{\partial z} = \frac{\partial}{\partial x_i}\left(\Gamma \frac{\partial c}{\partial x_i}\right) \qquad (1)$$

W Fall velocity of sediment particles, U Flow rate, X Dimension and Γ is total confusion and diffusion coefficient of molecular diffusion coefficient. Value of Γ as the coefficient of viscosity ν_t and obtained by turbulence model.

$$\Gamma = \frac{\nu_T}{S_c}$$

Number S_c is Schmidt an integer value is between 0.7 And 1 (The default value SSIIM2.0, is 1). To calculate the bed load in the default software SSIIM2.0 the empirical formula of bed at Van Rhine (Van Rijn) Used is as follows.

$$\frac{q_b}{d^{1.5}\sqrt{\frac{(\rho_s-\rho)}{\rho}g}} = 0.053\frac{\left[\frac{\tau-\tau_c}{\tau_c}\right]^{1.5}}{d^{0.3}\left[\frac{(\rho_s-\rho)g}{\rho\nu^2}\right]^{0.1}}$$

q_b Bed load discharge per unit width, d Average particle diameter (D_{50}), τ Bed shear stress, τ_c Critical shear stress for sediment movement (Shields diagram is obtained) and ρ, ρ_s : The mass per unit volume of water and sediment grains are.

MATERIALS AND METHODS

Laboratory flume

The experiments have been conducted in a recirculating rectangular prismatic glass-sided open-channel main flume being 40.00 m long, 2.00 m wide and 1.20 m deep. The flume slope was horizontal; the requested bottom slope of the mobile bed has been achieved by adjusting the sediment layer. The main flume was subdivided longitudinally into two separate channels. The first channel, 20.00 m long and 1.50 m wide represents the actual testing facility with the mobile bed. The second one, 0.47 m wide, constitutes a lateral channel enabling to evacuate the laterally diverted discharge.

The side weir was located on the right channel bank 5.00 m or 40

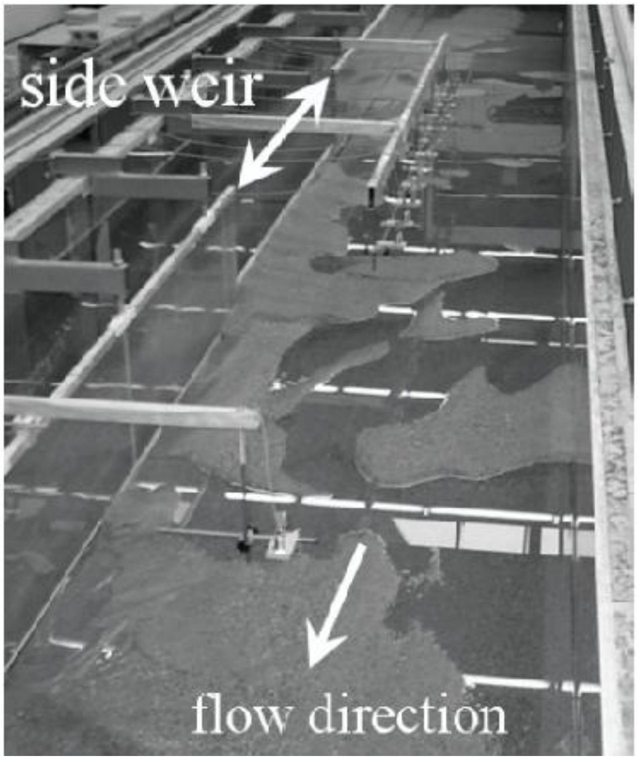

Figure 1. Laboratory setup with main channel and mobile bed, side weir and evacuation channel.

flow depths from the main channel inlet (test series B). The crest was horizontal and rectangular with a crest width of 0.025 m. the up-and downstream weir corner consisted of semi-circle profiles.

At the end of the mobile bed reach a plate has been installed to fix the sediments. The collection of bed material transported out of the main channel was attained by the arrangement of three restitution basins at the channel outlet.

A group of test have been carried out in a 20.00 m long, 1.50 m wide and 1.20 m high rectangular flume and consisted of a 3.00 m long side weir, that they were simulated in SSIIM2.0.

The overall flow regime has been subcritical. The average initial bottom slope was 0.21%. The mobile bed was characterized by a median particle size of d_{50}=0.72 mm. During the simulation the water surface, the 2D-velocity field, the side overflows discharge and sediment supply was measured.

NUMERICAL MODELING AND ANALYSIS RESULTS

The software SSIIM2.0 field network solutions, has been done in the editor of network software. In order to reduce computation time, network size has compacted in spillway due to velocity gradient. For the dimensions of a network 12 * 31 * 276 used (From left to right, respectively, the number of grid lines in the x, y and z). The network created by network software in SSIIM2.0 is as shown in Figure 1. Sediment transport roughness for calculation was about d_{50} = 0.00072. Figures 2 and 3 showed Channel shape and its spillway.

The final shape of the substrate with one side weir (condition B) has been showed in Figure 4. This study presents the development and comparison performed in the numerical model SSIIM2.0 and a prototype. This study examined the model results with respect to those observed in the field as shown in Table 1) in order to determine whether the numerical model (SSIIM2.0) is able to predict velocity distribution in the study reach.

Results of the experiments have been shown on the graph (Figure 5). According to Figure 5 discharge with sediment and without sediment is close together. The difference between them was about 10%, so there is a little difference and it’s ignored.

Figure 6 showed the view of mesh network, and Figure 7 showed surface bed vectors.

Conclusions

In this study systematic experimental flume has been simulated in SSIIM2.0. According to the result, water and sedimentation simulation in SSIIM2.0 can show the situation of the flume in any characteristics.

For determining the water flow, sediment transport, bed deposition and its pattern SSIIM2.0 can be used effectively at all stages of project. Care is required to prepare grid and control file. It is strongly recommended

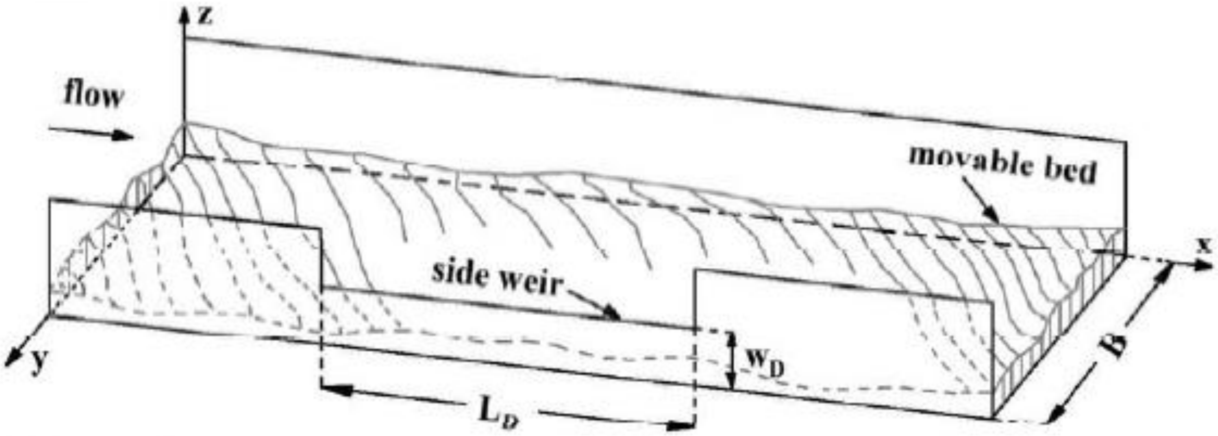

Figure 2. Definition sketch of experimental setup for one side weir.

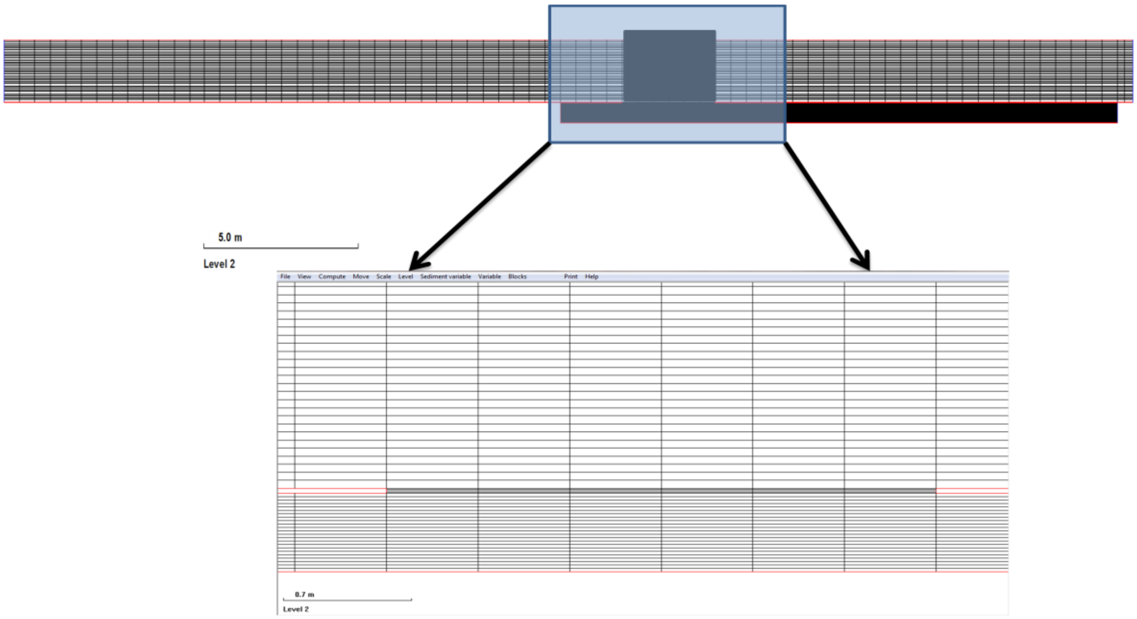

Figure 3. View of the mesh network in SSIIM2.0.

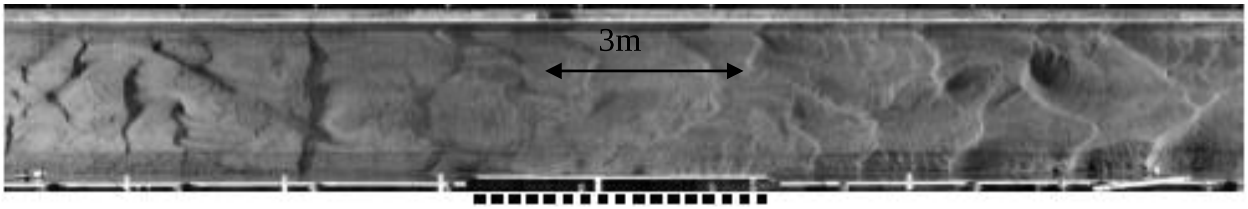

Figure 4. The final shape of the substrate with one side weir (condition B).

for further study SSIIM has great potential.

According to the results obtained by this study, the following conclusions are reached:

1. The rate of erosion and sedimentation over time has been an increasing trend, so that in the early minutes of the start of the calculations, changes in the bed has had

Table 1. channel characteristics in B(with one side weir).

No. of experiment	No. of weirs (n_D)	Length of weir crest (L_D(m))	Sill heigh t(w_D (m))	Bottom Slope (S_0 (%))	Upstream discharge(Q_1 (l/s))	Sediment supply ($Q_{sb/in}$) (kg/min)
B01	1	3.00	0.10	0.2	131	8.70
B02	1	3.00	0.10	0.2	181	17.73
B03	1	3.00	0.10	0.4	177	9.10
B04	1	3.00	0.10	0.1	98	9.67
B05	1	3.00	0.10	0.2	144	16.72
B06	1	3.00	0.10	0.3	148	17.61

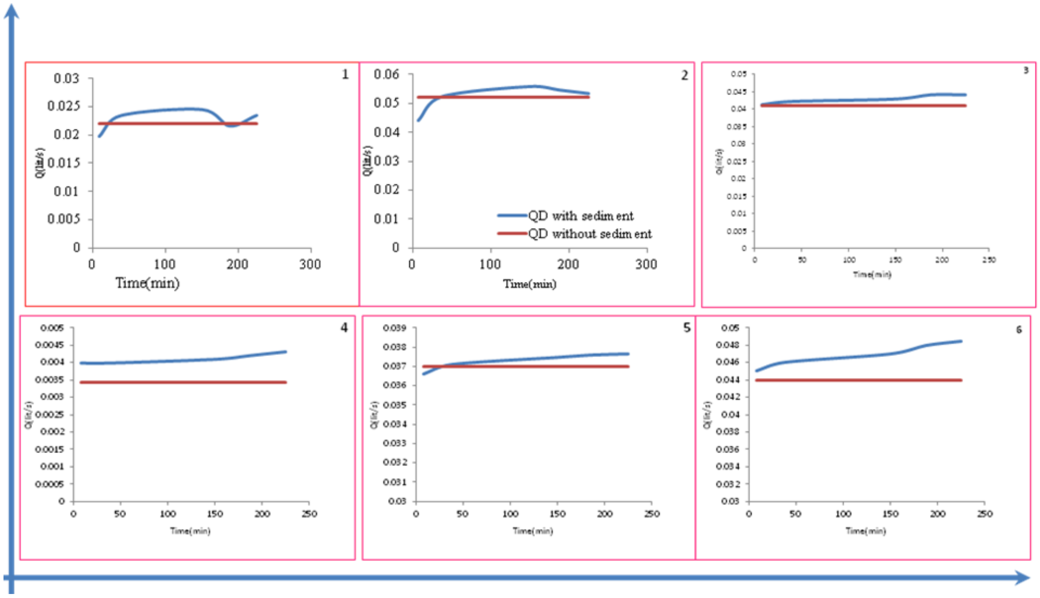

Figure 5. View of the morphological changes in flow.

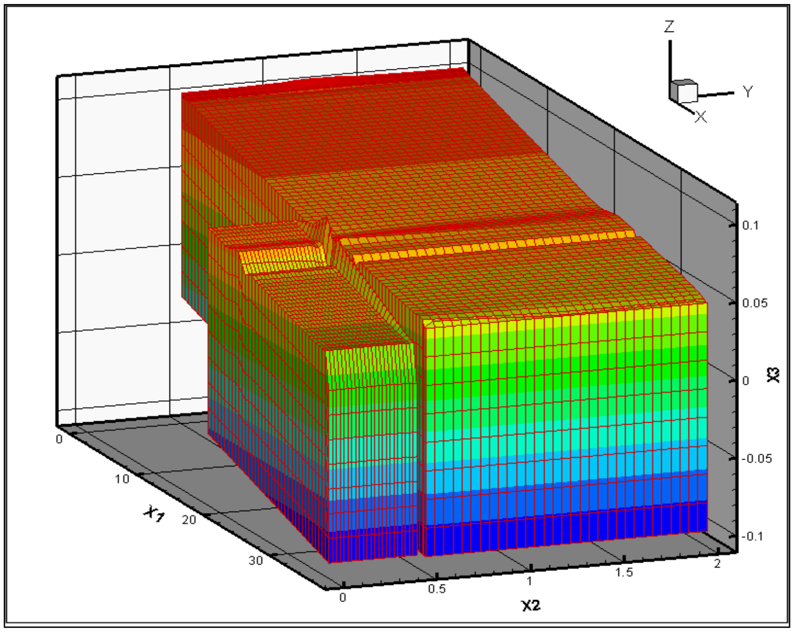

Figure 6. View of the mesh network in Tecplot360.

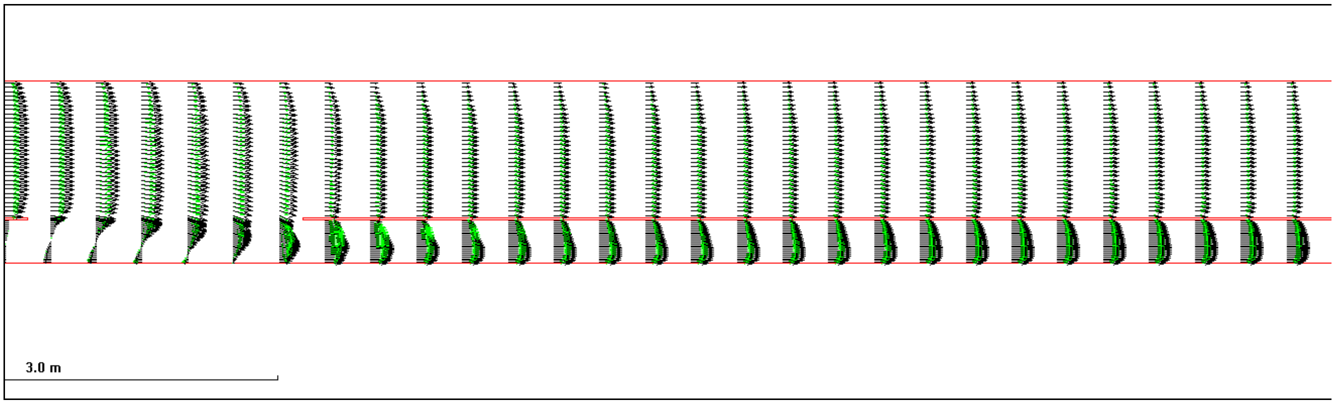

Figure 7. Surface bed vectors.

a reduced rate of change over time.

2. A good relation was observed between the measured and computed values of velocity at the study reach in three dimensions.

3. The SSIIM is one of the useful tools to predict the velocity distributions in three dimensions which gave good idea about the behavior of the flow velocities.

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