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Numerical Investigation of Internal Flow Properties around Horizontal Layered Trees by Using the Reynolds Stress Model

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Abstract: The aim of this article is to numerically explore the effects of a horizontal double layer of trees (HDLT) across the whole width of the channel on the flow structures under a steady flow rate and subcritical conditions. The numerical domain was established in ANSYS Workbench, and post-processing (i.e., meshing + boundary conditions) along with simulation was carried out by utilizing the computational fluid dynamics tool FLUENT. The three-dimensional (3D) Reynolds stress model and Reynolds-averaged Navier–Stokes equations were used to analyze the flow properties. The numerical model was first validated and then used for simulation purposes. Two varying configurations of HDLT were selected, represented as Arrangement 1 (tall emerged trees (T_t) + short submerged trees (S_t)) and Arrangement 2 (short submerged trees (S_t) + tall emerged trees (T_t)), along with different flow heights. The model accurately captured the simulated results, as evidenced by the vertical distributions of the velocity profiles and Reynolds stresses at specific locations. The strong inflection in velocity and Reynolds stress profiles was observed at the interface of S_t, contributing to turbulence and giving rise to vertical transportation of momentum between flow layers. While these profiles were almost constant from the beds to the tops of trees at those locations lying in taller trees (T_t), there was an approximate 31–65% increase in streamwise velocities at locations 1–6 in cases 1–2, along with a 54–77% increase at locations 7–10 in cases 3–4, in the unvegetated zone ($Z > 0.035$ m) compared to the vegetated zone ($Z < 0.035$ m). The magnitude of turbulence kinetic energy and the eddy dissipation rate were significantly larger inside the short submerged and tall emerged trees as compared to the unvegetated region, i.e., upstream and downstream regions. Similarly, the production of turbulence kinetic energy was approximately 50% and 70% greater inside the tree region ($Z < 0.035$ m) as compared to above the shorter trees during cases 1–2 and 3–4, respectively.

Keywords: horizontal double layer of trees; Reynolds stress modeling (RSM); ANSYS Workbench; Fluent; velocity distribution; Reynolds stresses

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1. Introduction

Tsunamis are catastrophic because they can destroy manmade structures and natural landscapes, and they can even take human lives [1]. Two massive tsunamis (2004, Indian Ocean; 2011, Great East Japan) occurred at the beginning of the 21st century, causing devastating havoc [2,3]. Tsunami defenses became a necessity after these massive tragedies. Several artificial (hydraulic infrastructure) and natural (coastline vegetation) approaches have been suggested for tsunami prevention [4]. Artificial structure development may be out of reach for certain developing nations because of the high initial capital outlay that is usually required [5]. Therefore, studies have concentrated on the importance of natural structures such as coastline vegetation, since they are regarded as an effective source of tsunami prevention and promote an ecologically friendly environment [6–9]. Data collected