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# Prediction of hydraulic jump length downstream of multi-vent regulators using Artificial Neural Networks

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**KEYWORDS**

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**Abstract** Multi-vent regulators are widely used in Egypt. Operation system of gates affects the characteristics of the flow downstream (DS) of multi-vent regulators. The current study aimed toward introducing the artificial intelligence technique as a new modeling tool in the prediction of the characteristics of the flow downstream of multi-vent regulators under the management and operating systems of multi-gates. Specially Artificial Neural Network (ANN) is utilized in the current study in conjunction with experimental data to predict the relative length of the submerged hydraulic jump (HJ) occured DS of multi-vent regulators under the different cases of gates operation. The results show that ANN technique is very successful in simulating the relative submerged hydraulic jump length occurred in stilling basins downstream of multi-vent regulators better than multiple linear regression (MLR).


## 1. Introduction

The management of the operation system of the multi-gates plays an important role for precising the characteristics of flow DS of multi-vent regulators. Fahmy [1], investigated the free HJ using sills under the gates with different DS slopes and different heights. Different operating systems of gates were employed. For three-vent regulators, it is preferred to open the two separate vents instead of the two adjacent ones for the same flow conditions. Operating the three vents gives maximum length of the HJ when compared to opening one vent and two vents.

Abdel-Aal et al.[2], analyzed the properties of the free HJ formed just DS of multi-vent regulators in radial stilling basin. Different operating systems of the multi-vent regulators were tested under the same flow conditions. Theoretical models for the symmetrical and asymmetrical operation were derived. Elfiky [3], studied the effect of end-sill on the characteristics of the free hydraulic jump created DS of multi-vent regulators in a radial stilling basin. This end sill was used to control and increase the jump stability and consequently reduce the construction costs. Abdel-Aal [4], studied the effect of angled solid deflector in controlling free HJ created DS of multi-vent regulators in a radial SB. Theoretical and statistical models for

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**Nomenclature**

| | |
|---|---|
| $B$ | width of channel (L) |
| $b_t$ | total widths of the opened vents (L) |
| $\sum b_d$ | sum of widths of the deflectors from Side view projection (L) |
| $e$ | expansion ratio, $B/b_t$ (–) |
| $F_1$ | inflow Froude number (–) |
| $L_b$ | basin length (L) |
| $L_d$ | distance between current deflector and the beginning of the basin (L) |
| $L_J$ | the jump length (L) |
| $n$ | no. of the working vents (–) |
| $Q$ | discharge ($L^3$ $T^{-1}$) |
| $S$ | degree of submergence, $Y_3/Y_1$ (–) |
| $Y_1$ | initial depth of the jump (L) |
| $Y_3$ | back up water depth just downstream the gate (L) |
| $Y_t$ | tail water depth at the end of the jump (L) |
| $Z_d$ | height of deflector (L) |
| $\gamma$ | specific weight (M $L^{-2}$ $T^{-2}$) |
| $\eta$ | factor related to flow condition (–) |
| $\acute{\eta}$ | factor related to operating system of gates (–) |
| $\Psi$ | central angle of deflector (–) |

*Abbreviations*

| | |
|---|---|
| ANN | Artificial Neural Network |
| DS | downstream |
| HJ | hydraulic jump |
| MLP | multi-layer perceptions |
| MLR | multiple linear regression |
| PE | processing element |

different operating systems were derived. Sauida [5], studied the effect of sharp radial current deflector in controlling the submerged hydraulic jump created DS of multi-vent regulators. The different parameters (location, height, angle, width) of the sharp radial current deflector had been studied experimentally. The management and operating systems of multi-gates were tested under the same flow conditions. Statistical model was proposed to compute the length of the submerged hydraulic jump based on the result of the dimensional analysis using multiple linear regression analysis.

Sauida [6], studied experimentally the separation of flow for a sudden expanding stilling basin at the downstream of multi-vent regulators. He found that the percentage area of reverse flow is dependent mainly on the expansion ratio ($e$), and partially on the Froude number under gates ($F_g$). A statistical model was developed based on multiple linear regression, to predict the percentage area of reverse flow at the downstream of multi-vent regulators.

Sauida [7], investigated the effect of expansion ratio, and type of gates operation on the discharge of a multi-submerged flow gates. He found that, increasing the expansion ratio and the asymmetric operation of gates has a positive effect on the discharge coefficient. Dimensionless general equation for computing the coefficient of discharge of the sluice gate is developed using the multiple regression analysis.

In this research paper, an accurate prediction model using the Artificial Neural Network was developed to predict the relative length of the submerged hydraulic jump created DS of multi-vent regulators under different cases of gates operation. These results of the ANN model were compared with the statistical one of Ref. [5].

### 1.1. Applications of ANN

Artificial Neural Networks were applied in many branches of engineering sciences. In hydraulic Engineering, Artificial Neural Networks were applied effectively. Negm et al. [8] investigated an ANN model to predict the characteristics of spatial hydraulic jump formed at asymmetric sudden expansion and in symmetric diverging channel. The results of the ANN models were compared to regression and theoretical models, and also, were compared to experimental data. It was found that the ANN model is much better than the other developed models. Esmaeili Varaki and Omid [9] adapted an ANN with multilayer perception structure, to model conjugate depth and gradually expanding jump length. The optimal models are capable of predicting conjugate depth and jump length for a wide range of conditions. Güven et al. [10] developed an ANN models to simulate the mean pressure fluctuations beneath a hydraulic jump occurring on sloping stilling basins. Multi-layers feed a forward neural network with a back-propagation learning algorithm to model the pressure fluctuations beneath such a type of hydraulic jump (B-jump). The results of the ANN models are found to be superior to the regression models and are in good agreement with the experimental results due to relatively small values of error (mean absolute percentage error).

Abdeen [11] utilize the ANN technique in investigating the impact of submerged aquatic weeds on the water surface profile in an experimental flume that supplies water to different distributaries. Several ANN models were developed to predict the water surface profile pattern when the upstream water depths in the main vegetated channel are higher than the smooth channel water depths for the same flow rates. The results show that the ANN technique is very accurate in simulating the water surface profile with the existence of submerged aquatic weeds. Salmasi [12] developed ANN models, for calculating the energy dissipation of flow over stepped spillway chute. The outcomes are valid for a wide range of stepped chute geometry and flow conditions. Bonakdari et al. [13] presented numerical analysis and prediction of flow field in a 90° bend using ANN and GA. Results of ANN that had been trained using GA and BEP indicate that the velocity field is predicted with good approximation in both training methods and it is concluded that the proposed procedures are useful for velocity prediction in channel bends. Salazar et al. [14] analyzed the radial-gated spillways, and the Oliana Dam is considered as a case study and the discharge capacity was predicted both by the application of a level-set-based free-surface solver and by the use of traditional empirical formulations. The results of the analysis were then used for training an ANN to allow real-time predictions of the discharge in any situation