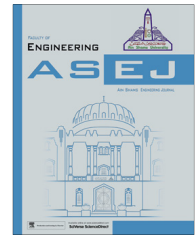




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Design of alluvial Egyptian irrigation canals using artificial neural networks method

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Abstract In the present study, artificial neural networks method (ANNs) is used to estimate the main parameters which used in design of stable alluvial channels. The capability of ANN models to predict the stable alluvial channels dimensions is investigated, where the flow rate and sediment mean grain size were considered as input variables and wetted perimeter, hydraulic radius, and water surface slope were considered as output variables. The used ANN models are based on a back propagation algorithm to train a multi-layer feed-forward network (Levenberg Marquardt algorithm). The proposed models were verified using 311 data sets of field data collected from 61 man-made canals and drains. Several statistical measures and graphical representation are used to check the accuracy of the models in comparison with previous empirical equations. The results of the developed ANN model proved that this technique is reliable in such field compared with previously developed methods.

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1. Introduction

What are the dimensions of a stable channel? Engineering concerned with the design of such channels asked themselves this question many years. The design of stable erodible channels is a complex process involving numerous parameters, most of which cannot be accurately quantified. The complexity of erodible channel design process results from the fact that in

such channels, stability is dependent not only on hydraulic parameters but also on Properties of the material that composes the bed and boundaries of channel. Despite decades of research, the task of designing stable alluvial channels, or stabilising natural rivers, is only partly supported by an adequate theory. Historically, there have been three approaches to determining the stable (non eroding non depositing) dimensions of such channel: (i) regime approach, Farias et al. [1] and El-Alfy [2], (ii) tractive force approach, Henderson [3], Singh [4] and Akan [5], and (iii) extremal hypothesis, Huang and Nanson [6] and Huang et al. [7]. Many authors have done pioneering work in what has become known as the regime concept, among of them Lacey [8], Yalin [9] and Savenije [10]. In fact, there is often considerable doubt expressed as to the generality of these equations inasmuch as sediment load can be highly varying and different from place to place and it was assumed that these

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Nomenclature

A	area of channel cross-section	S	water surface slope
B	bed width of channel	s_j	effective incoming signal
d_s	median size of sediment particle = d_{50}	T	top water surface width
f	Lacey's silt factor	V	mean flow velocity
g	gravitational acceleration	X_i	incoming signal from neuron (i)
K_s	a coefficient (sub-s being 1, 2, 3)	Y	flow depth
n	manning coefficient	y_i	outgoing signal
P	wetted perimeter	w_{ji}	weight for the signal x_i from cell i to j .
Q	discharge		
R	hydraulic radius		

channels were free from vegetal and underwater growth and fairly straight. However, it is coincidental that most field channels have vegetation at the water margins, Parker [11].

Kumar et al. [12] conducted experiments relevant to the regime behaviour of an alluvial canal affected by seepage in a large laboratory flume under various discharge and seepage conditions. They used the regime theory to determine the regression equations for the canal dimensions under stable conditions. Mathukrishnavallaisamy et al. [13] proposed a method for estimation of longitudinal dispersion co-efficient using regime channel concept. They concluded that changing the discharge of flow along direction of flow can change the stream geometry also. Madvar et al. [14] evaluated the potential of simulating regime channel using artificial neural networks and concluded that ANN can simulate the width, depth and slope of alluvial regime channel; however, their analysis was concerned rivers with sediment transport.

Lacey [8] described the geometry of stable alluvial canals (in metric units) as follows;

$$P = 4.83Q^{1/2} \quad (1)$$

$$R = 0.48(Q/f)^{1/3} \quad (2)$$

$$S = 0.00029Q^{-1/6}f^{5/3} \quad (3)$$

In which P is the wetted perimeter, R refers to the hydraulic radius, S is the water surface slope, Q describes the flow rate and f is the silt factor defined as;

$$f = 1.76\sqrt{d_s} \quad (4)$$

where d_s is the sediment diameter in millimetres.

A lack of a clear criterion for determining Lacey's silt factor is one of the major objections to his approach. Swamee et al. [15] tested Lacey's regime equations for river Brahmaputra and found that these do not match.

El-Attar [16] identified the following equations (in metric units) to describe the Egyptian canals in regime;

$$Y = K_1Q^{0.314} \quad (5)$$

$$Y/B = K_2Q^{-1/6} \quad (6)$$

$$S = K_3Q^{-1/6} \quad (7)$$

In which Y is the flow depth, B is the bed width, and K_1 , K_2 and K_3 are coefficients depending on channel category and flow characteristics.

For stable canals in Egypt, Khattab et al. [17], Bakry and Khattab [18] deduced the following empirical equation for the mean velocity (in metric units);

$$V = KY^{1.6} \quad (8)$$

In which K is a coefficient depending on the channel material. While Bakry [19] proposed the following formula;

$$V = 0.396R^{1.45}S^{0.282} \quad (9)$$

Ali [20], using method of synthesis for dimensional analysis, developed the following relations in SI units;

$$Y = 0.92Q^{0.4} \quad (10)$$

$$B = 4.16Q^{0.4} \quad (11)$$

$$S = 7.5 * 10^{-3}(d_s)^{0.415}Q^{-1/6} \quad (n \leq 0.04) \quad (12)$$

and

$$S = 3.6 * 10^{-3}(d_s)^{0.415}Q^{-1/6} \quad (n > 0.06) \quad (13)$$

in which n is the manning coefficient.

From the foregoing it appears that the regime of earthen canals in Egypt still requires more studies leading to a precise practical approach suitable for modern design of alluvial canals.

To get a discrete formula to be used, some effective parameters should be disregarded, and the accuracy of the predicted results will decrease. In the last-view decades, neural networks have been applied to many applications in science. The main objective of this study is to predict alluvial channel dimensions using ANN method. The performance of the proposed ANN model is then compared with three different conventional regime based methods.

2. Collected field data

Four main groups of data used in this study. The first was the data published by the ministry of irrigation (M.O.I.) and the second was the data collected by the design Egyptian canal group (DECA). Two other groups were published by EL-Attar [16,21], one for canals and the other for drains. For more details about the field data can be found in Saleh [22], Bakry [19], and El-Attar [16,21]. The data cover all grades of irrigation canals starting from distributary canals to branch canals and carrier canals. Table 1 shows the range of variables for the

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