The Egyptian Int. J. of Eng. Sci. and Technology

Vol. 17, No. 2 (April 2014)

EIJEST

EFFECT OF SUBMERGED WEEDS ON WATER FLOW IN OPEN CHANNELS*

Gamal M. Abdel-aal[1], Amany A. Habib[1], Abd- elazeem M. Ali[2] and Marwa F. Shaheen[+3]

[1] Water Eng. Dept., Faculty of Eng., Zagazig Univ., Egypt

[2] Hydraulic Research Institute, National Water Research Center, Egypt

[3] Ministry of Water Resources and Irrigation, Egypt

ABSTRACT:

Whenever a cleaning process and removal of weeds from water channels is carried out, the weeds re-appear in a matter of weeks and sometimes days. This costs a lot of effort and money. Hence, there is an urgent need for harmonization between the presence of weeds of acceptable densities and to maintain water levels in the last reaches of the channels which are mainly infested by the weeds. The present paper aims to study experimentally the impact of the existence of submerged weeds on the flow characteristics in case of maintaining the water levels behind the infested areas. The data were collected using a laboratory flume of relatively large dimensions (60cm wide, 65 cm depth, and 20.8 m long) with fixed bed slope (0.0062). Flexible branched roughness elements were used with different intensities (0.0062, 0.0123, and 0.0246). The weeds intensities were tested with different discharges and different tail water depths. Dimensional analysis was used to correlate the flow characteristics to the other relevant parameters of the flow and weeds. Dimensionless general equations in terms of these parameters for computing both heading up, relative energy loss, Manning coefficient and relative shear velocity of the flow through the infested reach were developed and compared with the experimental data. The comparison proved a good reliability and high accuracy. The equation of Manning coefficient was reduced to the case of non-infested canals and verified with different irrigation canals (El-salam main canal and its branches Om El-Reesh , San El-hagar stage 2 and 3 and El-Sheikh Gaber canal).

KEY WORDS: Submerged weeds, Manning coefficient, Shear velocity, Heading up, Energy loss

---

EFFET DE MAUVAISES HERBES IMMERGÉES SUR L'EAU DÉBIT EN CONDUITES OUVERTES *

RÉSUMÉ:

Chaque fois qu'un processus de nettoyage et l'élimination des mauvaises herbes de canaux d'eau est effectuée , les mauvaises herbes réapparaissent dans une affaire de semaines et parfois des jours . Cela coûte beaucoup d'efforts et d'argent. Par conséquent, il ya un besoin urgent d'harmonisation entre la présence de mauvaises herbes de densités acceptables et à maintenir les niveaux d'eau dans les derniers bastions des canaux qui sont principalement infestés par les mauvaises herbes . Le présent document vise à étudier expérimentalement l'impact de l'existence de mauvaises herbes submergées sur les caractéristiques d'écoulement en cas de maintien des niveaux d'eau derrière les zones infestées . Les données ont été recueillies au moyen d'un canal de laboratoire de dimensions relativement importantes (60 cm de large , 65 cm de profondeur et 20.8 m de long) avec une pente de lit fixe (0,0062) . Éléments de rugosité ramifiés souples ont été utilisées avec des intensités différentes (0,0062 , 0,0123 , 0,0246 et) . Les mauvaises herbes intensités ont été testés avec différents débits et différentes profondeurs d'eau de queue . L'analyse dimensionnelle a été utilisé pour établir une corrélation entre les caractéristiques d'écoulement pour les autres paramètres pertinents de l' écoulement et les mauvaises herbes . Équations générales dimension en fonction de ces paramètres pour calculer les positions jusqu'à la perte d'énergie relative, coefficient de Manning et de la vitesse de cisaillement relative de l'écoulement à travers la portée infestés ont été développées et comparées avec les données expérimentales . La comparaison s'est avérée une bonne fiabilité et une précision élevée . L'équation de coefficient de Manning a été réduit au cas de canaux non infestées et vérifié avec différents canaux d'irrigation (canal principal El - salam et ses branches Om El - Reesh , le stade San El - Hagar 2 et 3 et El -Cheikh Gaber canal) .

MOTS CLÉS: mauvaises herbes submergées , coefficient Manning , vitesse de cisaillement , à la tête , la perte de l'énergie

---

* Received: 10/12/2013, accepted: 5/3/2014, Ref. No. 173, (original paper)

+ Contact author (shaheen20007@yahoo.com)

1. INTRODUCTION:

Weeds are one of the most important problems affecting channel efficiency and water distribution. Weeds cause many dangerous problems such as water velocity reduction, decreasing water flow, increasing in water level, and preventing water from reaching the canal end. So the presence of weeds may complicate the conveyance system operation. Flow resistance varies with type, maturity, and density of weeds and consequently affects the performance of the channel. So weeds have to be controlled to an acceptable level to improve the channels performance. Many researches have been carried out to study the effect of submerged weeds presence on the hydraulic characteristics of open channels. Gwinn, and Ree, (1980) [1], carried out series of tests on channels with green and dormant grasses after 25 years without maintenance. It was concluded that the presence of the bushes and trees in these channels reduces their capacities by 29% and reduces the velocity by 6%. While Khattab and El-Gharably, (1984) [2] observed a reduction in the discharge by 60% for a group of channels and drains covered by water Hyacinth. Khattab and EL-Gharably, (1990) [3], investigated the effect of thick mats of water Hyacinth on the hydraulic efficiency of canals and drains and concluded that the flow rate was reduced to 60% and 45% and Manning's roughness coefficient attained was 0.045 and 0.065 in large and small channels respectively. Abd El-Salam et al., (1991a, b) [4], studied the effect of submerged vegetation on the flow resistance in wide channels and on the hydraulic properties of earthen Egyptian canals. They deduced relations between mean velocity and both equivalent Manning's roughness coefficient and discharge for submerged vegetal canals dependent on the slope of the channel bed. Bakry, (1992) [5], studied the effect of composite roughness due to aquatic submerged weeds. He observed that in case of weeds covering the whole perimeter, the canal section had the lowest resistance to the flow. While in case of weeds covering the bed and one side, the cross section has the highest resistance, but in case of weeds covering the bed only, the section has a medium resistance to the flow. Bakry, (1992) [6] also studied effect of emergent weeds on the hydraulic roughness of earthen channels in Egypt and found that the flow velocity through vegetation parts almost equal to zero. Salama and Bakry, (1992) [7], developed modified formula for Manning's equation for two cases of weed distribution along the wetted perimeter (on the bed, and on the bed and the two side slopes). Badway, (1998) [8] found that the hydraulic efficiency was reduced to 61% and 70% in channels having plants occupied 10% and 20% of the water cross section respectively. El-Samman et al. (1999)[9] concluded that both density and distribution of submerged aquatic weeds had a significant impact on the efficiency and equitability of water distribution. Increasing the density or distribution of submerged weeds reduced the flow and obstructed water to reach downstream end of the canal and consequently the distributaries were subjected to shortage of water. Wilson and Horritt, (2002) [10] pointed out that a uniform Manning’s coefficient could be assumed when the relative submergence (the ratio of flow depth and effective height of the vegetation) was above two. Gado, (2003)[11], used flexible branched roughness elements to simulate weeds upstream a two opened equally gates regulator. He concluded that the weeds increase the water surface profile slope upstream the regulator and has nearly no affect downstream it, disturb the uniformity of velocity distribution profiles upstream the regulator, decrease the discharge coefficient, increase the energy loss, and its effect decreases by decreasing the height of gates opening. Also Osman, (2004) [12], studied experimentally the effect of submerged weeds upstream a two gates regulator one of them is fully close and the other was opened and found that the same results of Gado. El-Samman, (2007) [13] found that the velocity profile distribution was not uniform in channel infested by submerged weeds and affected by weeds density and distribution on bed. And submerged weeds on channel bed have a great effect on flow direction. Chen, et al (2009), [14] used two different aquatic plants with 5 plant densities. They found that aquatic plants affected channel flows more roughly in low velocities, less significantly during increasing velocities, and finally dismally as if non-existing when the velocity reached to a certain point due to plant's lodging and the retardance coefficient under a high discharge was similar to that for a non-vegetated channel. Abdelmoaty, et al (2011)[15], recommended to apply the biological control means by using grass carp to overcome the aquatic weed infestation during the current operation stages and use of rice straws to retard and control the spread of algae in the infested canals.

The main objectives of this investigation are to study the impact of the existence of weeds on the flow characteristics in case of maintaining the water levels behind the infested areas to obtain new selectors taking into account the existence of weeds by the extent that does not affect the water line behind these weeds. And not raised it in front of the infested areas which may cause flooding in the upstream, or water logging in the land surrounding the channels. In the case of the presence of weeds in drains, the rising of water upstream the infested areas may lead to water flooding drainage pipes at their ends. This could lead to the return of water from the drains in these pipes, which certainly having a bad impact on the operations of agricultural field drainage.

2.THEORETICAL APPROACH

Figure 1 shows a definition sketch of an infested open channel by submerged weeds. The following function can be formed:

$$f\,(U, g, P, A, a_x, a_y, y, y_t, y_w, B, \rho, \mu, Q, L, L_w, n, h_w) \ldots\ldots (1)$$

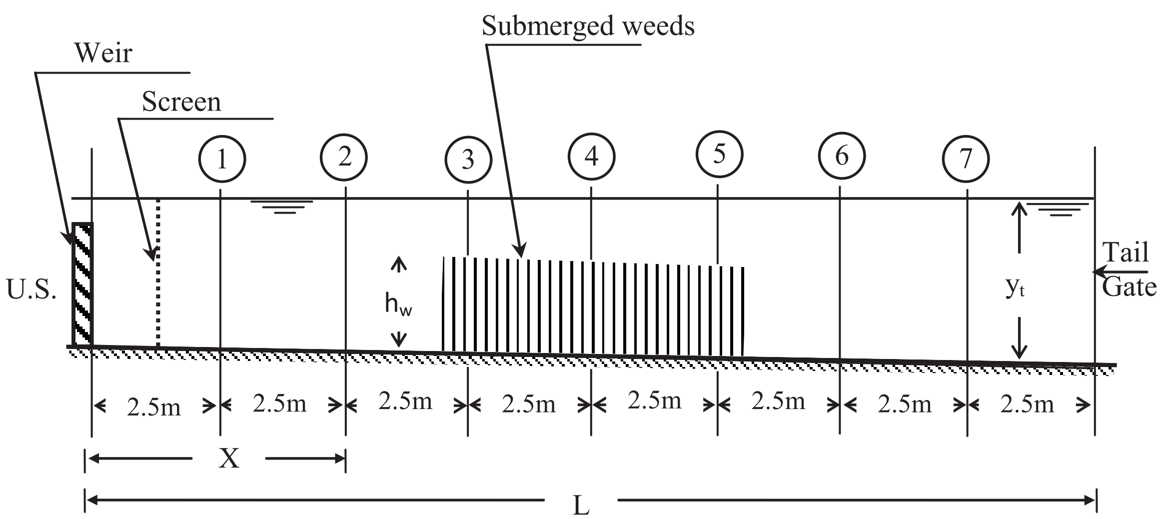

Fig. (1): Definition Sketch

Where A is the area of water cross section, B is the channel bed width, P is the wetted perimeter, g is the gravitational acceleration, n is the Manning's roughness coefficient, Q is The discharge of the channel, U is the mean velocity of flow, y is the U.S water depth, y_w is the U.S water depth in case of existence of weeds, y_t is the tail water depth, μ is the dynamic viscosity of fluid, ρ is the density of the fluid, a_x is the longitudinal spacing of submerged weeds, a_y is the transverse spacing of submerged weeds, L is the tested length , L_w is the infested length of the channel bed, and h_w is the height of submerged weeds Using dimensional analysis principle based on the three repeating variables ρ, g and y, Eqn. (1) becomes:

$$f\left(F_r\ , I_S\ , \frac{U}{U^*}\ , \frac{y_t - y_w}{y}, \frac{h_w}{y}, n\right) = 0 \quad \text{………(2)}$$

where Fr is the Froud number = $U/\sqrt{gy}$, U^* is the shear velocity $=\sqrt{gRS}$, S is the channel bed slope, R is the hydraulic radius, and I_S is the intensity of submerged weeds = $1/a_x a_y$.

Equation 3 can be written as follow:

$$\frac{U}{U^*} = \ \left(F_r\ , I_S\ , \frac{y_t - y_w}{y}, \frac{h_w}{y}, n\right) \quad \text{……………..…(3)}$$

Similar relationships for the energy loss ratio ($\Delta E/E_1$) could be obtained as follow:

$$\frac{\Delta E}{E_1} = \ \left(F_r\ , I_S\ , \frac{y_t - y_w}{y}, \frac{h_w}{y}, n\right) \quad \text{……………..…(4)}$$

3. EXPERIMENTAL WORK

The experimental work of this study was performed in the hydraulic laboratory of the Hydraulic Research Institute (HRI) - sponsored by the National Water Research Center (NWRC). The experimental work of this study was conducted using reinforced concrete flume of total length of 24 m, 60cm width and 65 cm depth. The discharges were measured using pre-calibrated weir US the channel. The tailgate fixed at the end of the flume was used to control the tail-water depth of flow. The channel bed slope was fixed as 0.0062. To simulate the submerged weeds a flexible branched roughness elements were used as shown in figure 2 and placed in the middle third of the flume as shown in photo 1 through a length of 6m with different intensities (I_S = 0.0062, 0.0123, and 0.0246). The weeds intensities were tested with four different discharges (25, 30, 35, 40 lit/s) and different tail water depths (25, 30 and 35cm) for each discharge. A typical test procedure consisted of (a) a selected discharge was allowed to pass. (b) The tailgate was adjusted until the required tail depth is obtained (c) Once the stability conditions were reached, the flow rate, water depths at seven different sections across the flow as shown in fig.1, the tail water depth, in addition to the velocity profile were recorded. Experimental data cover the following ranges: tail Froude number (F_t = 0.064 to 0.17), relative weed height (h_w/y_t = 0.57 to 0.8), and submerged weeds intensities (I_S = 0.062 to 0.0246).

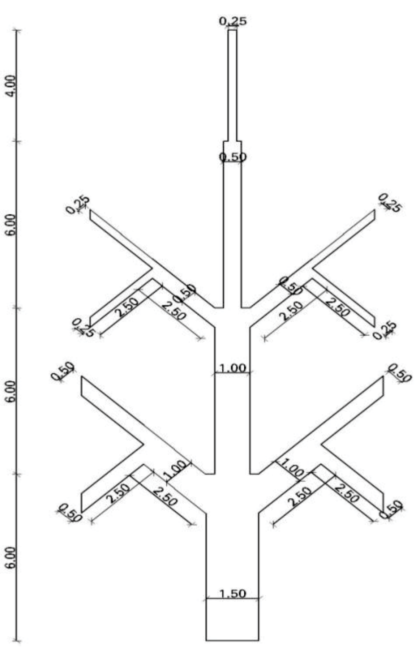

Fig. (2): Dimensions of one of the flexible roughness elements in cm

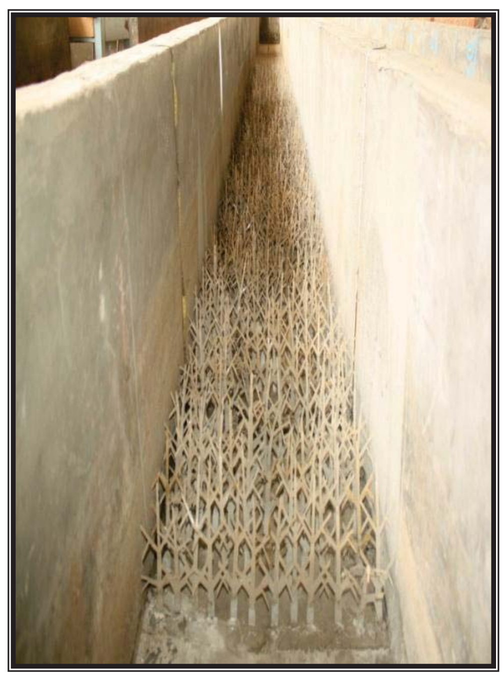

Photo (1): Arrangement of weeds in the flume

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

The study aims to adapt irrigation channels with the used irrigation systems in the presence of weeds as unacceptable phenomenon difficult healing. The experimental results of the present investigation will be analyzed in this part in comparison with the case of no weeds to obtain the impact of the existence of weeds on the hydraulic characteristics of the flow for infested channels.

4.1 Effect of Submerged Weeds on the Water Surface Profiles:

Figures 3, 4 and 5 show the channel water surface profiles of different weed intensities (I_S = 0.0062, 0.0123, and 0.0246) with the case of no weeds. The figures show the relationship between relative water depth y/y_t and the relative distance x/L for different F_t for each weed relative height (h_w/y_t = 0.8, 0.67 and 0.57) respectively. From the figures it was observed the water surface profile increase with the increase of tail Froude number values of F_t and with the increase of the weeds intensity in comparison with the no weeds case. It was also observed that the water surface slope increases with the increase in F_t for all values of weed relative height.

4.2 Effect of Submerged Weeds on the Heading up:

The heading up is the percentage of the increase of water depth at the upstream cross section due to the presence of submerged weeds. Figure 6 shows the relationship between the heading up $(y_w - y)/y$ due to submerged weeds and F_t for different weeds densities at different h_w/y_t. Where y_w and y are the U.S. water depths in the cases of weeds and no weeds respectively.

From this figure it is observed that the heading up increases with the increase of both F_t and weed intensity for the same weed relative height h_w/y_t. The heading up increases also with the increase of h_w/y_t for the same F_t and weed intensity. Table 1 shows the percentages of increase in heading up due to the existence of weeds.

4.3 Effect of Submerged Weeds on Energy Loss:

The relative energy loss $\frac{\Delta E}{E_1}$ through the tested reach was calculated and plotted against F_t for different weed intensities I_S at various values of h_w/y_t as shown in figure 7. The figure shows that $\frac{\Delta E}{E_1}$ increases with the increase of F_t and weed intensity for the same values of h_w/y_t in comparison with the case of no weeds. The figure also shows that $\frac{\Delta E}{E_1}$ depends on the stage of weed growth where the values of relative energy loss increase with the increase of weed relative height h_w/y_t for the same tail Froude number.

4.4 Effect of Submerged Weeds on Manning Coefficient (n):

To detect the effect of submerged weeds on Manning coefficient (n), depending on the experimental data values of n for all sections (7sections) through the tested reach were plotted against the relative positions of each section (x/L). Figure 8 shows the relationship between n and x/L for different weeds intensities at various h_w/y_t for chosen values of F_t. Also the figure illustrates that Manning coefficient n increases with the increase of the weed intensity for the same section comparing with the case of no weeds and the effect of weeds decreases with the increase in section relative position. Table (2) clarifies the percentages increase of n with respect to the case of no weeds, for tested weed intensities at various h_w/y_t . From this table it is noticed that percentages of the increase of n increases with the increase of I_{sub}, F_t and h_w/y_t. While figure 9 which represent the relation between n and Ft at h_w/y_t = 0.8 at different sections along the tested reach as shown in fig. 1. Also the figure shows that the values of n decreased with the increase of F_t (i.e. with the increase of the flow) for both the same section and the relative weed height.

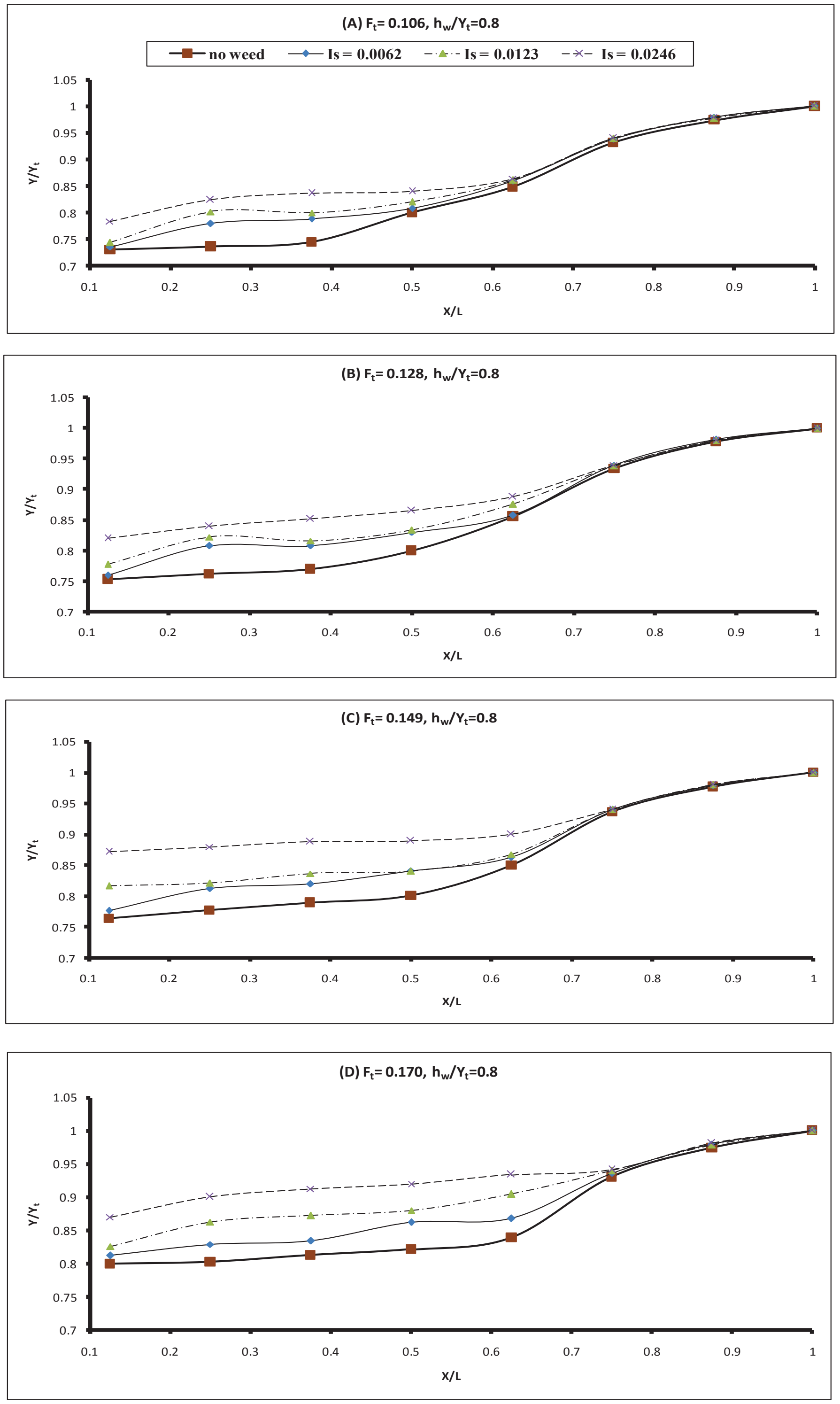

Fig.(3) Water surface profiles for different values of F_t and h_w/y_t=0.8

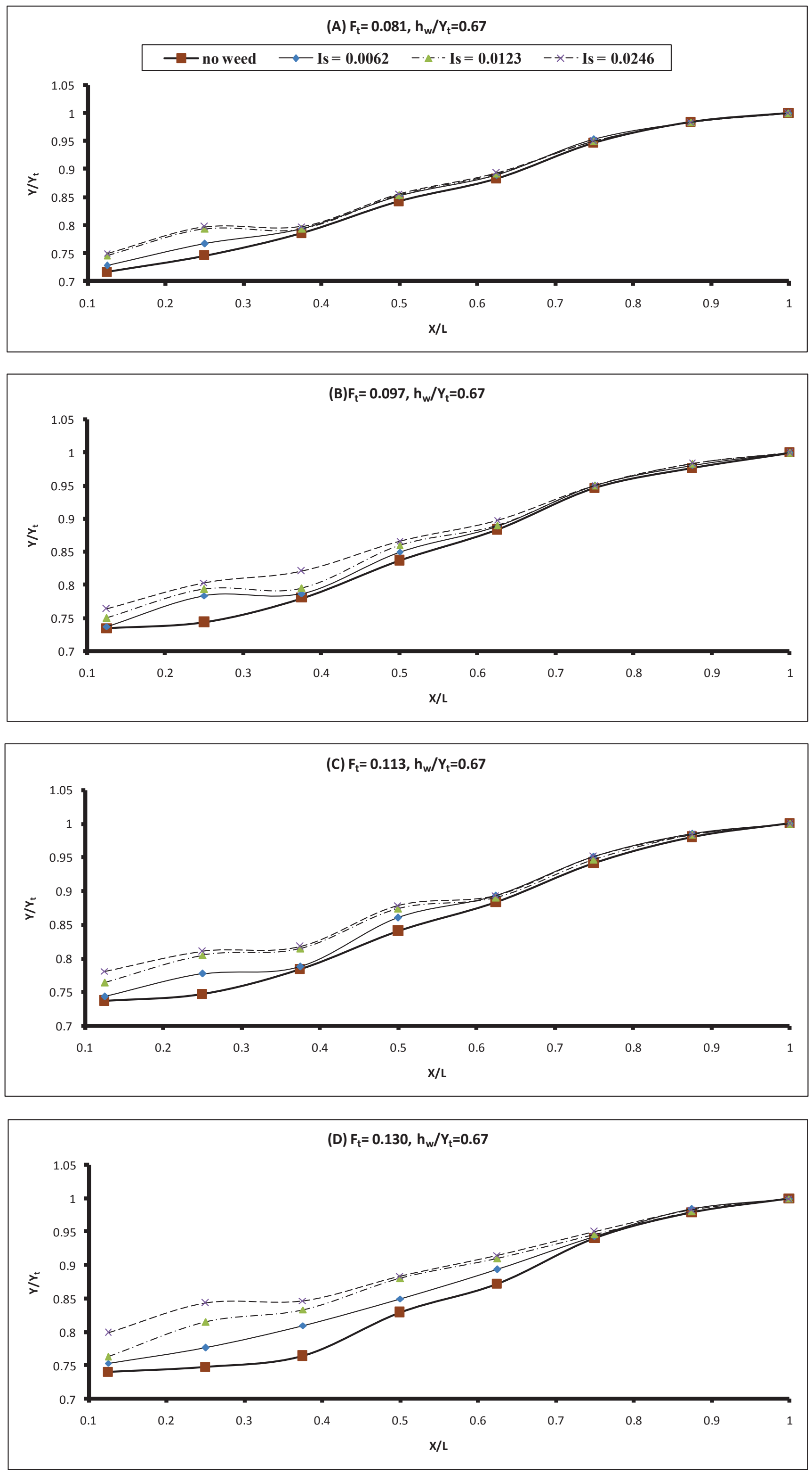

Fig.(4) Water surface profile for different values of F_t and h_w/y_t=0.67

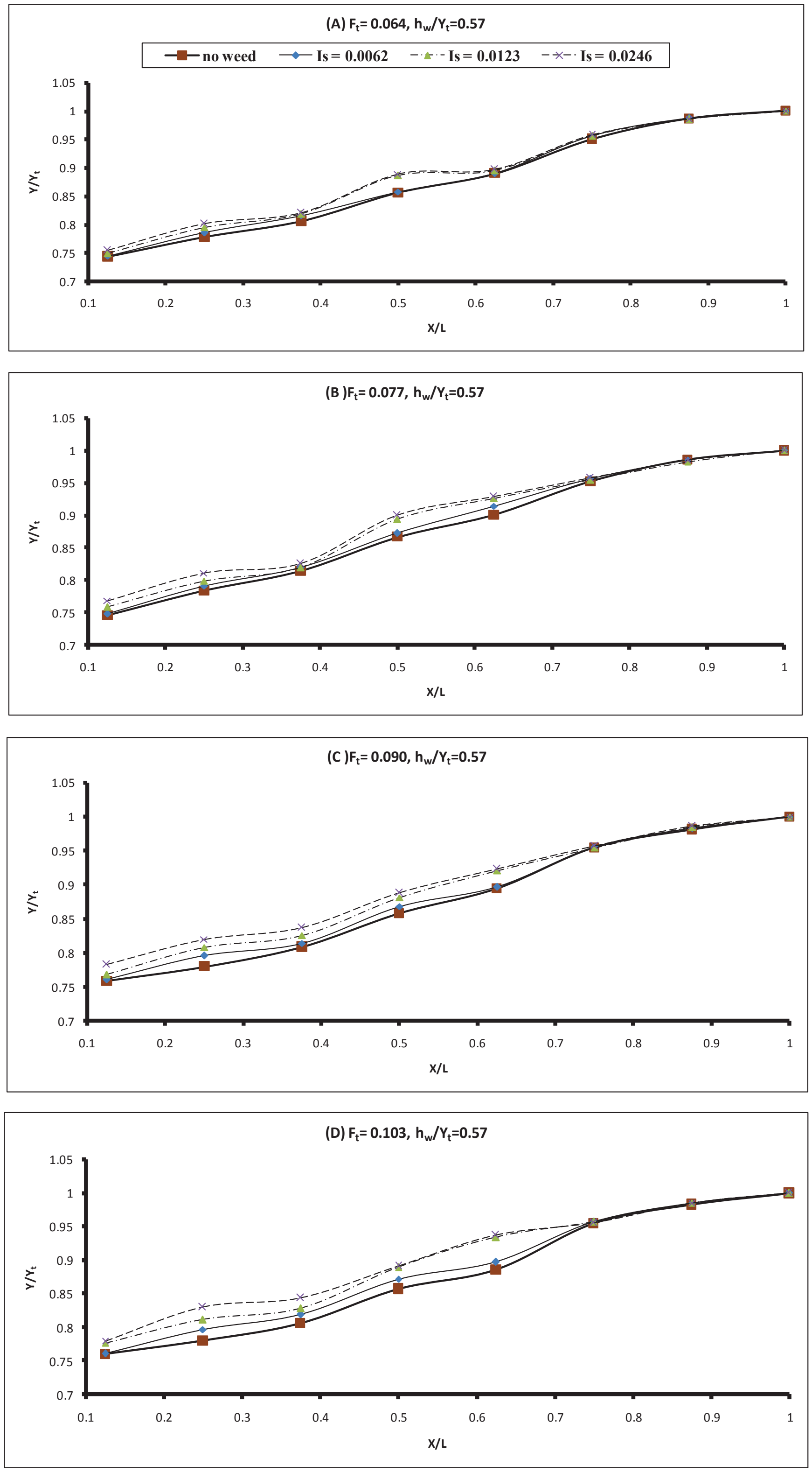

Fig.(5) Water surface profile for different values of F_t and h_w/y_t = 0.57

Table (1): %age increase of heading up as a function of h_w/y_t and I_s

h_w/y_t	%age increase of heading up		
	I_S = 0.0062	I_S = 0.0123	I_S = 0.0246
0.8	0.77 – 1.6	1.86 – 7.853	7.34 – 13.25
0.67	0.45 – 2.25	2.273 - 4	4.14 – 7.88
0.57	0.19 – 0.38	0.77 – 1.724	1.47 – 3.16

Table (2): %age increase of Manning coefficient as a function of h_w/y_t and F_t

h_w/y_t	F_t	%age increase of Manning coefficient (n)		
		I_S = 0.0062	I_S = 0.0123	I_S = 0.0246
0.8	0.106 0.128 0.149 0.170	3.22 3.39 3.41 3.44	4.75 4.92 5.30 6.97	8.13 8.64 11.72 11.85
0.67	0.081 0.097 0.113 0.130	1.54 1.93 2 3.55	2.77 3.05 4.09 6.46	3.19 4.70 5.09 8.86
0.57	0.064 0.077 0.090 0.103	0.66 0.90 0.93 1.45	1.81 2.10 2.53 3.64	2.23 2.98 3.70 4.59

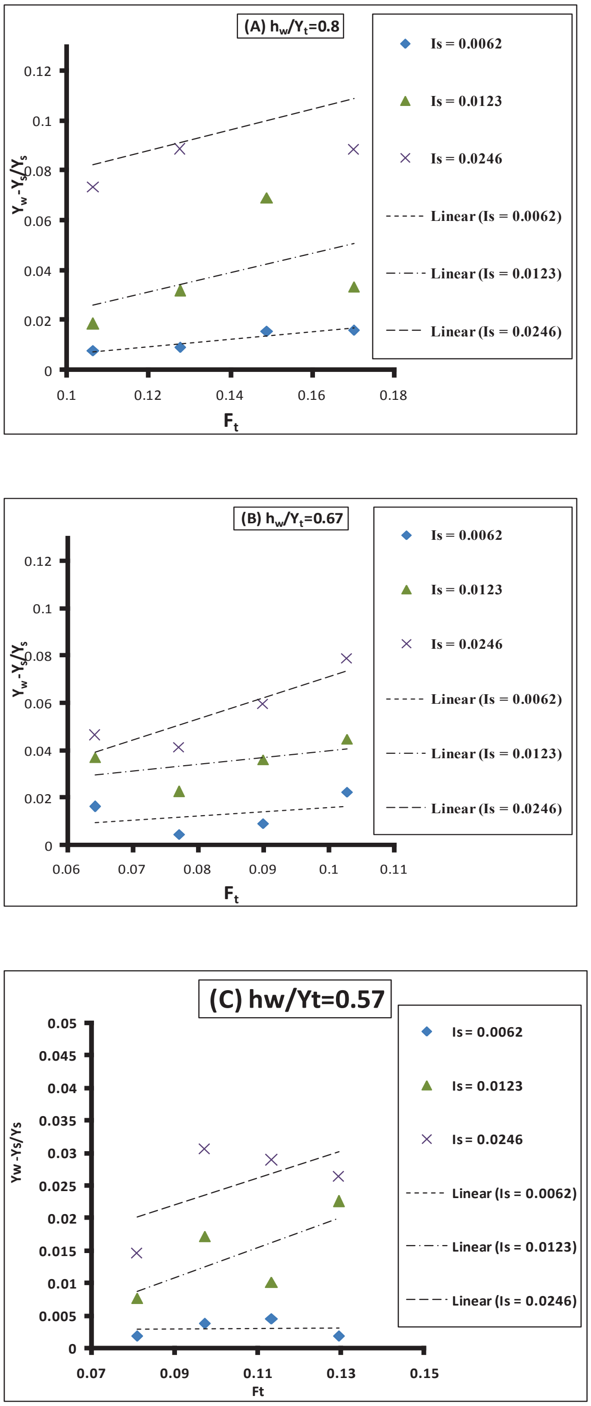

Fig. (6) Relationship between heading up and F_t for different weeds densities at different h_w/y_t

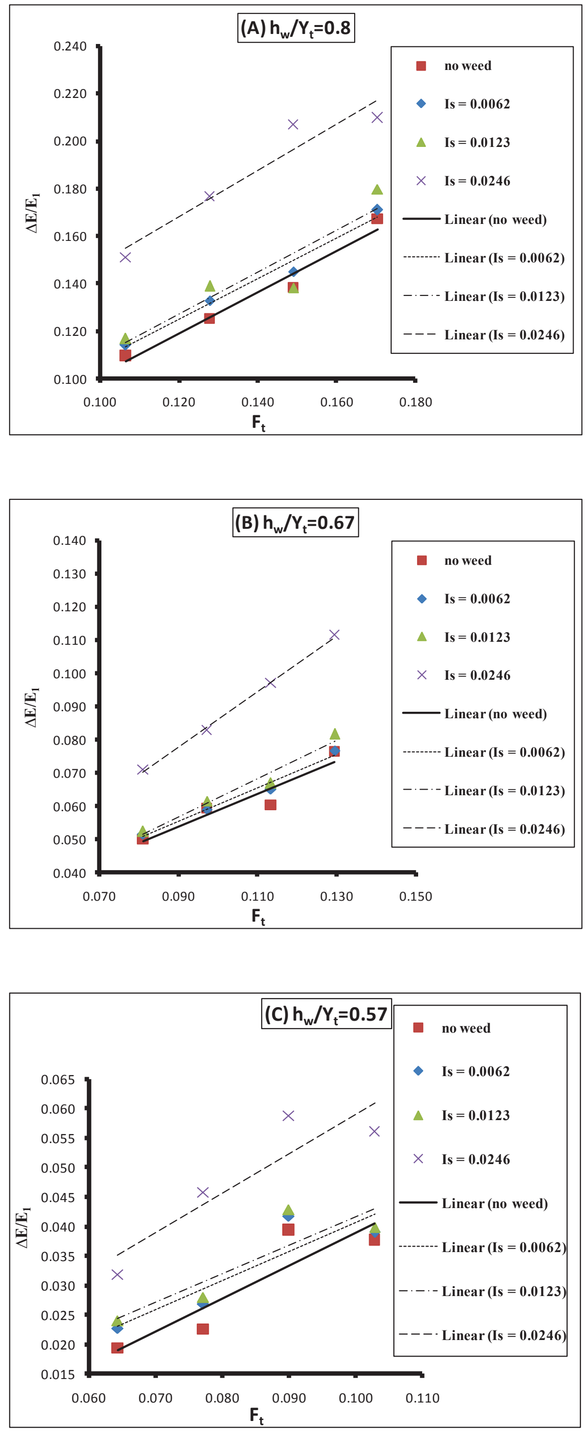

Fig. (7) Relationship between relative energy loss and F_t for different weeds densities at different h_w/y_t

4.5 Effect of Submerged Weeds on Relative Shear Velocity:

The vertical velocity profiles were measured at the 7 sections in the transverse direction of the flume. From the measured velocity profiles it was noticed that the velocity profiles in the infested channel were changed in magnitude and shape within the channel cross section and reverse velocities occurred just behind weed elements. Figure 10 represents the relation between U*/U (relative shear velocity) and the relative positions of the sections (x/L) for different weeds intensities at various h_w/y_t for chosen F_t. This figure exhibits that the values of U*/U increases with the increase of the weed intensity for the same tail Froude number and relative weed height at each section in comparison with the case of no weeds and the effect of weeds decreases with the increase in section relative position.

4.6Effect of Submerged Weeds Relative Height on Relative Energy Loss:

Figure 11exhibits the relationship between the relative energy loss $\frac{\Delta E}{E_1}$ through the tested reach and F_t for different weeds relative height h_w/y_t (0.57, 0.67 and 0.8) at various values of I_S (0.0062, 0.0123 and 0.0246). This figure shows that $\frac{\Delta E}{E_1}$ increases with the increase of F_t and relative weeds height for the same value of I_S. This means that the relative energy loss increases with the increase in weeds stage of growth.

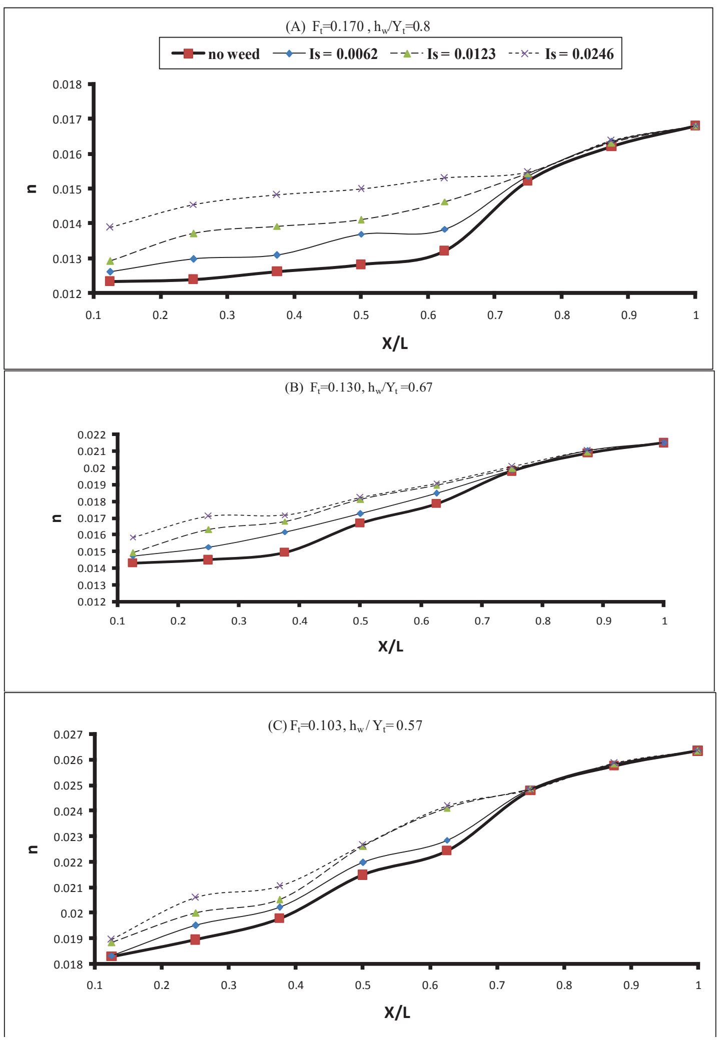

Fig. (8) Relationship between Manning coefficient (n) and x/L for different values of weeds intensity at various h_w/y_t

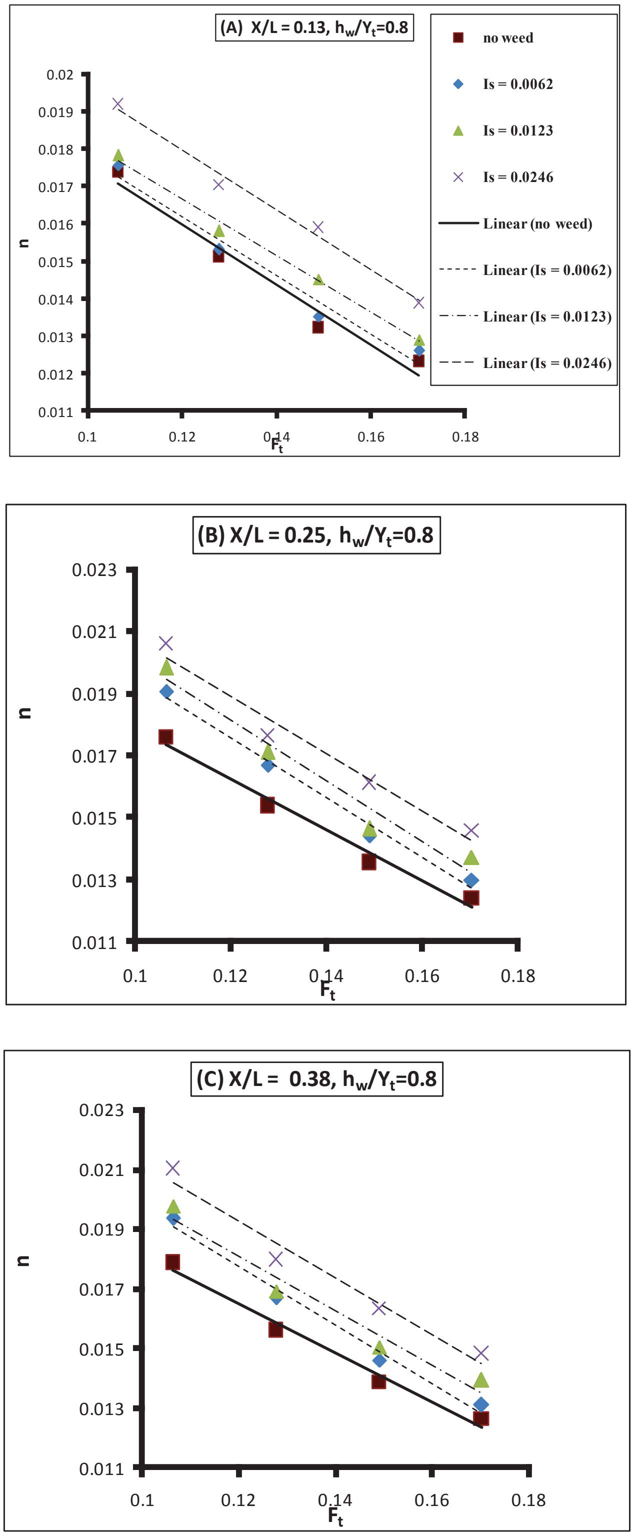

Fig. 9 (a) Relationship between Manning coefficient (n) and F_t for h_w/y_t = 0.8 at different sections (X/L= 0.13→ 0.38)

5 STATISTICAL REGRESSION ANALYSIS

Linear multiple regression analysis were used to analyze the experimental data. Many trials were made with different variables to obtain the best agreement between the experimental and the predicted values. The statistical equations (5, 6 ,7 and 8) were built to predict the heading up, the relative energy loss $\Delta E/E_1$, Manning coefficient, and the relative shear velocity respectively as follow;

$(y_w-y)/y = -1.04 + 0.17\, I_s + 0.107\, f_t - 0.012\, h_w/y_t + 0.047\, y_t/y + 0.97 y_w/y$ ………………………..(5)

$\Delta E/E_1 = 0.18 + 1.7\, I_s + 0.93\, F_t + 0.29\, h_w/y_t - 0.16 y_t/y - 0.2\, y_w/y$ ………………………...…(6)

$1/n = -103.4\, I_s + 346.58 F_t + 4.46\, h_w/y_t + 11.02\, y_t/y - 4.79\, y_w/y$ ………...…(7)

$U_t/U^* = 1.22\, I_s + 17.19 F_t - 0.39\, h_w/y_t + 0.15\, y_t/y + 0.28\, y_w/y$ …………...………………………..(8)

Figures (12) through (15) show a comparison between the measured and the predicted values using statistical Equations (5, 6, 7, and 8) respectively. The applicability ranges of equations (5-8) are h_w/y_t (0.57- 0.8), I_S (0.0062- 0.0246) and F_t (0.064 - 0.17).
The comparison indicates a good agreement between predictions and experimental data (R^2 = 0.99, 0.91, 99 and 0.99 respectively).

6 APPLICATION

The experimental data were used to deduce a statistical equation for the Manning coefficient (n) Eq. (7) for the case of submerged weeds existence as previously mentioned. For the case of no weeds and approximately uniform flow in horizontal channels where the water depths are the same in any reach Eq. (7) reduced to the following form:

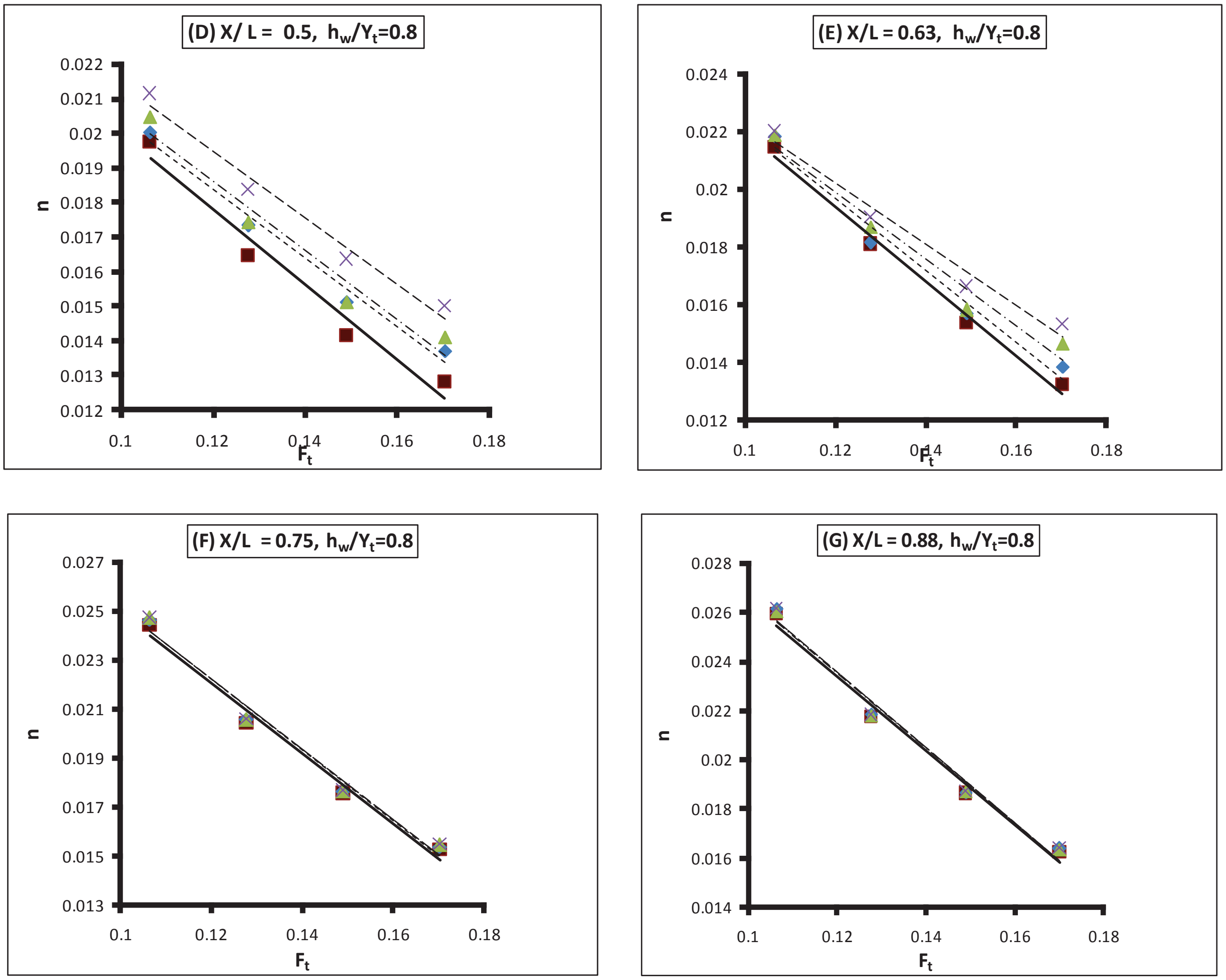

Fig. 9 (b) Relationship between Manning coefficient (n) and F_t for h_w/y_t = 0.8 at different sections (x/l = 0.5 →.0.88)

$$\frac{1}{n} = 346.58\, F_n + 11.02 \qquad (9)$$

Where F_n is the Froude number for the canal section under consideration. Equation (9) is applicable for F_n (0.064 - 0.17). This equation is used to calculate the Manning coefficient for Elsalam main canal at different sites and its branches (Om El-Reesh, San El-Hagar stage2, 3 and El-Sheikh Gaber canals) at daily measurements field data. The data of Elsalam main canal were obtained from its longitudinal section and the data of Om Elreesh and San Elhager stage 2, 3 were acquired from USAID, calibration report, Ministry of Water Resources and Irrigation, El-Mansoura, while the data of El-Sheikh Gaber canal was obtained from the water resources and irrigation sector for the development of North Sinai, the general administration of Tina plain. Table 3 introduces

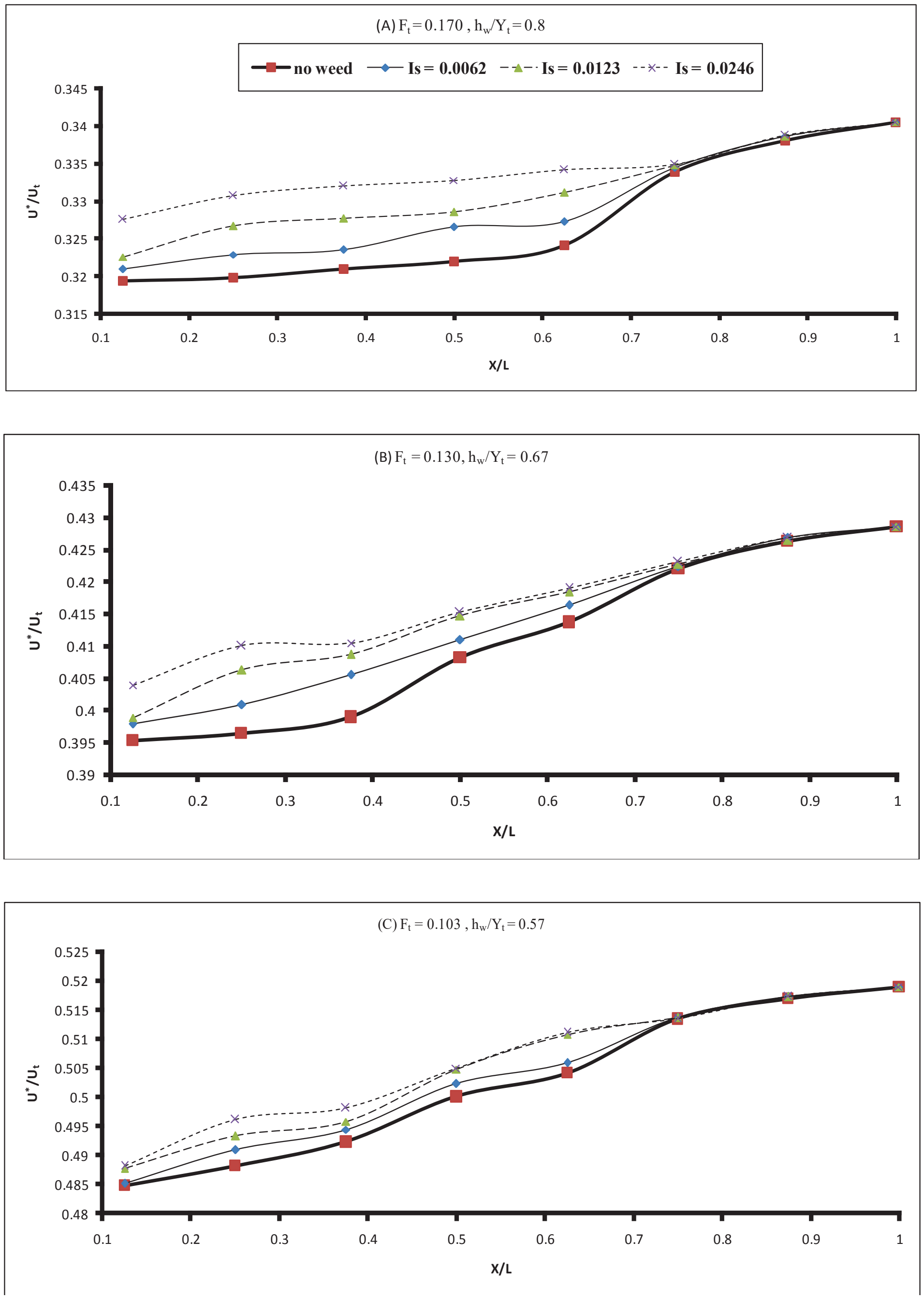

Fig. (10) Relationship between U*/U and x/L for different weeds intensity and various h_w/y_t

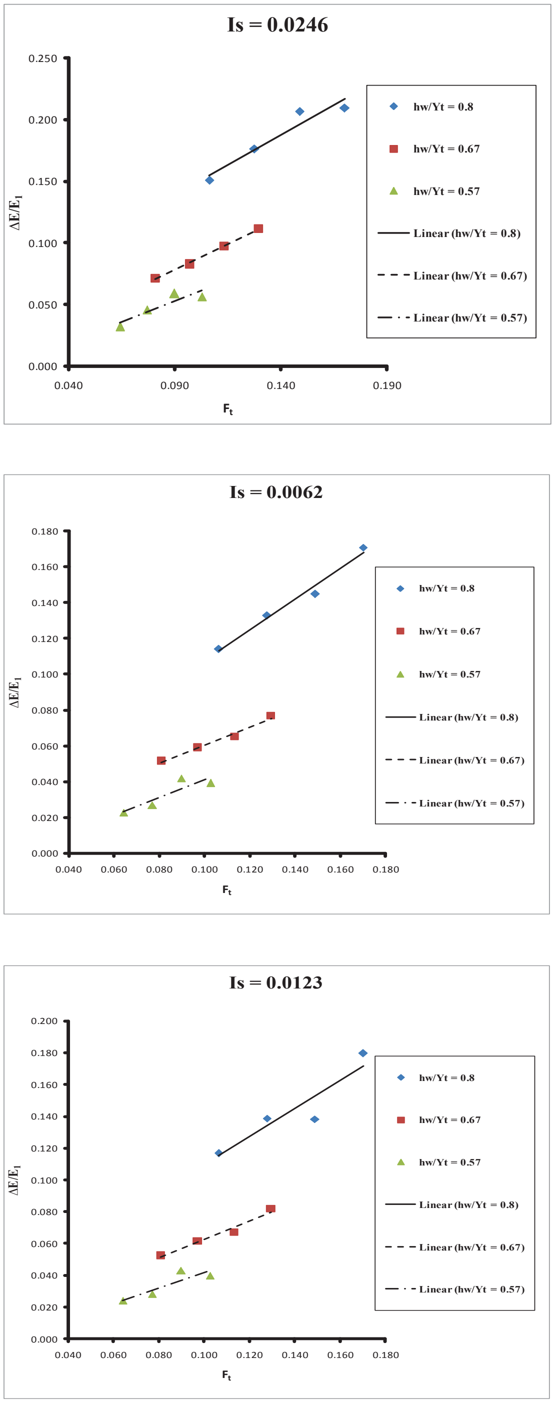

Fig. (11) Relationship between relative energy loss and F_t for different h_w/y_t at various I_S

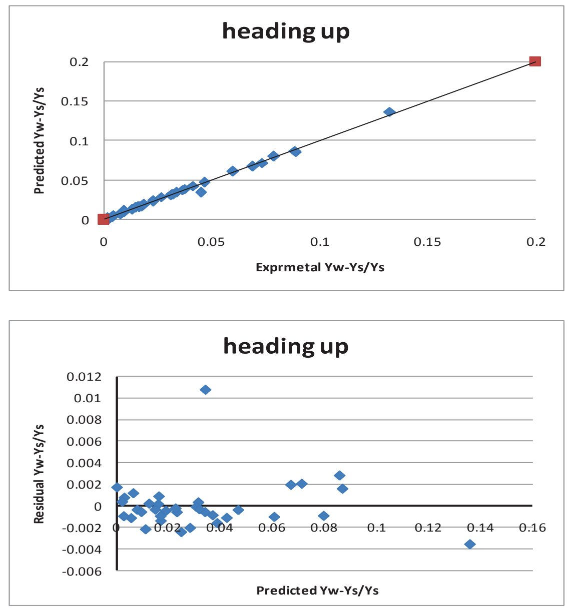

Fig. (12) Results of the heading up using (Eq. 5)

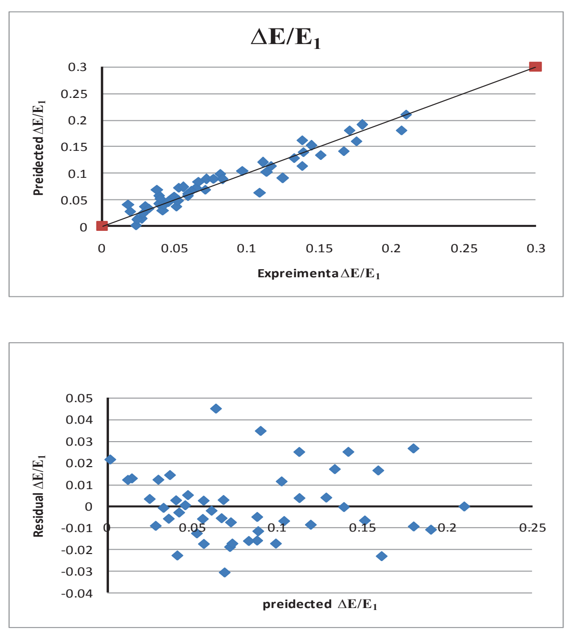

Fig. (13) Results of the relative energy loss using (Eq. 6)

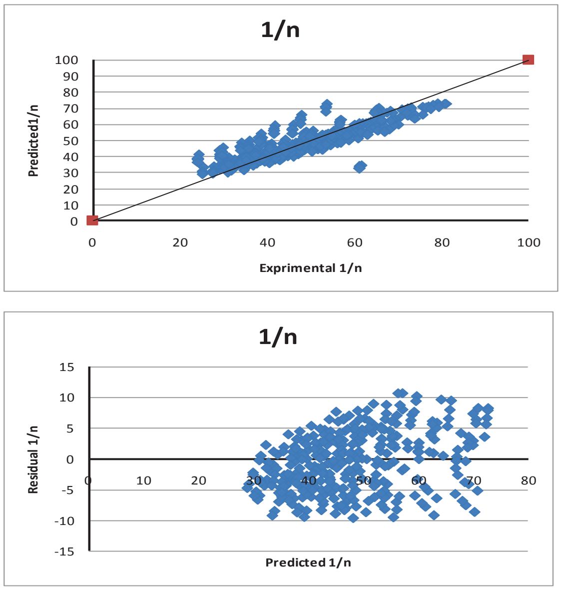

Fig. (14) Results of the relative energy loss using (Eq. 7)

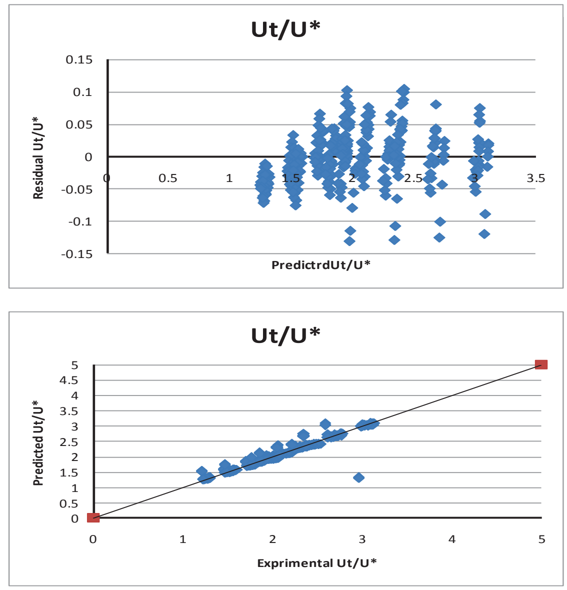

Fig. (15) Results of the relative energy loss using (Eq. 8)

the percentages of error between the calculated values using Eq. (9) and the field values of Manning coefficient (calculated using the data of the canals and Manning equation). The average percentage of error between the calculated values using Eq. (9) and the field values of Manning coefficient for all the irrigation canals used in the verification was 5.88%. The comparison between the field and the calculated values for all the canals used in the verification are shown in Fig. 16. For lined canals with time, weeds grow throw the canal lining joints and cracks which increase the canal roughness. So Eq. (9) can be used for theses canals in its original form Eq. (7) to obtain the roughness coefficient for the infested regions. The advantage of the proposed Eq. (7) is its simplicity in practice and its capability to estimate the roughness coefficient for infested and non-infested canals.

7.CONCLUSIONS

An experimental investigation was conducted in a laboratory flume using flexible branched roughness elements of different intensities to investigate the effects of the presence of the submerged weeds on the flow characteristics in case of maintaining the water levels behind the infested areas. The results indicated that:

- The water surface profile increase with the increase of tail Froude number F_t and with the increase of the weeds intensity and its slope increases with the increase of F_t.
- The heading up increases with the increase of both F_t and weed intensity for the same weed relative height h_w/y_t. It increases also with the increase of h_w/y_t for the same F_t and weed intensity.
-

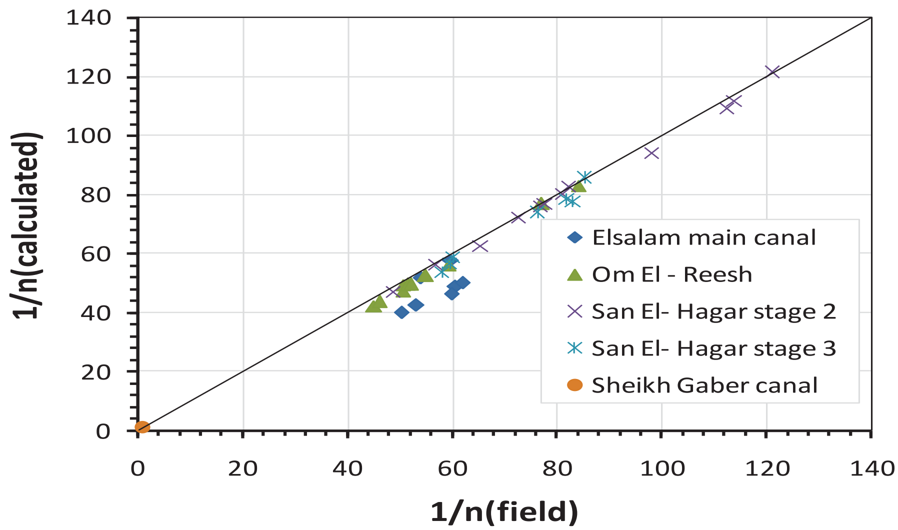

Fig. (16) Comparison between calculated and field values of 1/n for different irrigation canals

Table (3): Percentage error between calculated and field values of Mannings coefficient n for Elsalam main canal and its branches

site	site	b/y	% error
San Elhagar stage3	1	23.64	3.854
Daily measurments field data through year 2010	2	19.40	5.211
	3	15.48	1.574
	4	20.00	0.887
	5	15.29	7.040
	6	23.64	1.678
	7	28.89	3.870
Shikh Gaber canal	1	10.000	23.787
Daily measurments field data through year 2013	2	10.222	17.316
	3	10.000	11.452
	4	11.500	3.609
	5	10.824	3.045
	6	10.698	2.888
	7	11.500	5.773
	8	11.795	5.802
	9	11.358	4.861
	10	11.220	4.676
	11	10.824	4.137
	12	10.110	3.114
	13	10.824	2.447
	14	10.110	6.053
	15	10.337	24.728
	16	11.500	0.868
	17	11.646	2.998
	18	11.646	2.254
	19	11.705	0.822
	20	11.795	1.049
	21	11.795	2.601
	22	11.646	3.922
	23	11.948	0.191
	24	11.646	3.147

site	site	b/y	% error
Elsalam main canal	Km23.050	10.41	8.926
	Km35.000	11.11	6.580
	Km54.160	15.04	2.245
	Km55.160	13.86	3.756
	Km69.750	14.36	7.379
	Km75.250	12.44	7.084
	Km88.000	10.75	9.296
Om Elreesh	1	20.00	5.016
Daily measurments field data through year 2013	2	18.57	8.905
	3	11.40	12.625
	4	15.48	2.954
	5	18.57	0.201
	6	16.67	8.100
	7	13.68	11.022
	8	15.29	13.192
	9	13.98	13.372
	10	16.25	9.380
San Elhagar stage2	1	17.81	1.064
Daily measurments field data through year 2013	2	23.64	5.457
	3	17.33	2.029
	4	26.00	4.840
	5	20.00	4.460
	6	15.29	2.141
	7	15.29	3.911
	8	12.38	9.700
	9	26.00	6.291
	10	20.00	3.288
	11	13.68	12.174
	12	17.33	1.900

- The relative energy loss through the tested reach increases with the increase of F_t and weed intensity for the same h_w/y_t.
- The relative energy loss depends on the stage of weed growth its values increase with the increase of weed relative height h_w/y_t for the same tail Froude number.
- Manning coefficient increases with the increase of the weed intensity for the same section comparing with the case of no weeds and the effect of weeds decreases with the increase in section relative position.
- The percentages of the increase of Manning coefficient increases with the increase of I_s, F_t and h_w/y_t.
- The values of Manning coefficient decrease with the increase of the flow for both the same section and the relative weed height.
- The relative shear velocity increases with the increase of the weed intensity for the same tail Froude number and relative weed height.

Empirical equations are developed to predict the heading up, the relative energy loss, Manning coefficient and the relative shear velocity through the submerged weeds infested reach. The results of the model indicated good agreement between the experimental and predicted values (R^2 = 0.99, 0.91, 99 and 0.99 respectively).

The empirical developed equation of Manning coefficient was reduced to the case of non-infested canals and verified with different irrigation canals (Elsalam, Om El-Reesh, San El-Hagar stage 2, 3 and El-Sheikh Gaber canals). The verification indicated that:

- There was an acceptable agreement between the calculated and the field values of Manning coefficient for different sites and discharges of the canals under consideration as shown in table (3).
- The average percentage of error between the calculated values and the field values for all the irrigation canals included in the verification was 5.88%.
- The equation can be used in its original form for old lined and unlined canals in case of submerged weeds infestation.
- The developed equations for flow characteristics are flexible to fulfill the flow and site implementation requirements, and simple in practice.

REFERENCES

1- Gwinn, W. R. and Ree, W. O., 1980, “Maintenance Effects on the Hydraulic Properties of a Vegetation- Lined Channels”, Soil and Water Division, ASCE, vol. 23, No.3, pp. 636-642.

2- Khattab, A. F. and El-Gharably, Z., 1984. “The Problem of Aquatic Weeds in Egypt and Methods of Management”, Proc. EWRS 3rd. Symp. On Weed problems in the Mediterranean Area, Lispona, Protugal, pp. 335-344.

3- Khattab, A.F and EL-Gharably, Z., 1990, “The Effect of Water Hyacinth on the Hydraulic Efficiency of the Irrigation System in Egypt and Its Management”, proc. of 14th Congress, International Commission on Irrigation and Drainage, ICID, Brazil.

4- Abd El-Salam, M. W., Khattab, A. F., Khalifa, A. A. and Bakry, M. F., 1991, “Towards a Flow Through a Wide and Submerged Vegetal Channels” , Proc. of African Regional Symposium on Techniques for Environmentally Sound, Water Resource Development, Alexandria, Egypt, pp.1-10.

5- Bakry, M. F., 1992, “Flow Resistance in Channel Section with Composite Roughness Due to Aquatic Weeds”, International Conference on Supplementary Irrigation and Drought Water Management, Vol. 2, Bari, Italy, pp. S3-18.1/S3-18.12.

6- Bakry, M. F., 1992, "Effect of Emergent Weeds on the Hydraulic Roughness of Earthen Channels in Egypt", Proc. of Al-

Azhar Eng. Second International Conference, vol. III , Cairo, Egypt , pp. 288-297.

7- Salama, M.M., and Bakry, M. F., 1992, "Design of Earthen Vegeted Open Channels", Water Resource Management, No. 6, pp. 149-159.

8- Badawy , H. A., 1998, "Effect of Aquatic Weeds on the Environment in Egypt", Journal of Water Science, Water Research Center, the 23th Issue, Cairo, Egypt, pp. 18-23.

9- El-Samman, T.A., Hosny M.M. and Ibrahim H.M, 1999 "Impact of Aquatic Weeds on Water Distribution Efficiency, the 2nd Inter-Regional Conference on Environment, Water Engineering Technologies for Sustainable Land use and Water Management, Lausanne, Switzerland.

10- Wilson C. A. and Horritt M. S., 2002, "Measuring the Flow Resistance of Submerged Grass", J. Hydrol. Process, 16(13): 2589-2598.

11- Gado, T. A., 2003, "Performance of Water Structures in Channels Infested by Aquatic Weeds", M.Sc. thesis, Tanta University, Tanta, Egypt.

12- Osman, E. A., 2004, "The Hydraulic Behavior of Vegetated Channels", M. Sc. thesis, Ain shams University, Cairo, Egypt.

13- El-Samman, T. A., 2007, "Velocity Distributions in Vegetated Channels" Eleventh International Water Technology Conference, IWTC11, Sharm El-Sheikh, Egypt.

14- Chen, Y. C., Lin, J. Y., Yang, H. C., 2009, " Retardance Coefficient of Vegetated Channels Estimated by the Froude Number " Ecological Engineering35,1027–1035,journalhomepage: www.elsevier.com/locate/ecoleng.

15- Abdelmoaty, M. S., Ibrahim, H. M., and. El Samman, T. A., 2011, " Protection of Open Channels from sand dunes movements (case study - Toshka Project) " Fifteenth International Water Technology Conference, IWTC-15, Alexandria, Egypt .