

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING



**Impact of Submerged Aquatic Weeds on Scour
Downstream Hydraulic Structures**

BY

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ABSTRACT

Most of the water channels in Egypt suffer from the infestation of aquatic weeds especially submerged weeds which cause a lot of problems for the open channels and the water structures such as increasing water losses, increasing the roughness of channels, increasing water energy losses, obstructing the water flow and reducing the efficiency of the water structures.

Many Researchers studied Scouring Phenomenon and proved that Scouring is a natural phenomenon caused by the flow of water in rivers and streams. It is most pronounced in alluvial materials. Many types of structures have altered river regimes, and impacts on the transport and deposition of sediment have resulted. Major floods and bridges cause changes in a river regime, bends and narrows of a river channel tend to scour during floods and fill at low flows, the bed material like sand help in scouring occurring and the bank erosion can occur during the big flow. They proved also that Structural failure induced by scour usually occurs in extreme cases of unsteady flows interacting with a given structure and with changing channel conditions, but there is no studies conducted on the Relation between the submerged aquatic weeds and Scouring downstream the hydraulic structures.

The main objective of this study is to investigate the effect of the presence of the submerged aquatic weeds with different densities, locations, and distributions on the scour downstream hydraulic structures.

In this research, branched flexible elements are used to simulate the submerged weeds; they are fitted on the constructed reinforced concrete flume with trapezoidal cross section, a regulator model with a vertical sluice gate is built on the flume.

Two hundred forty runs are conducted to achieve the objective. Experimental measurements (water surface profiles, discharges, velocities, Scour Depth, Scour Length, and Scour Hole Volume) and the relationships between the flow parameters are studied to show the effect of the submerged weeds on the scour downstream the solid apron, the water surface profile, and the velocity distribution.

The analysis of the experimental data concluded that Water surface profile, scour shape, velocity profiles, and scour dimensions are functions of the presence of submerged weeds with different densities, locations, and distributions. Presence of weeds decreases scour depth except Case of Presence low density weed upstream hydraulic structure and high density weed downstream at the same time with complete distribution on the cross section and case of high density weeds downstream hydraulic structure with left and bed distribution on the cross section. Presence of weeds downstream hydraulic structure decreases scour length. Presence of weeds decreases scour volume except Case of Presence of high density submerged weeds which are distributed in the bed and left side downstream hydraulic structure causes a maximum scour volume which is increased by 28.30 % than smooth case. Maximum scour depth for all cases was occurred with maximum discharge and minimum gate opening height and was located in the first third of the scour zone area D.S. apron at the left side of the cross section. Many equations were derived to determinate the effect of submerged weeds with different density, location, and distribution on the scour downstream hydraulic structure.

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NOTATIONS AND ABBREVIATIONS

This is the list of the symbols and abbreviations used in this thesis and their dimensions:

Symbols:

A	$[L^2]$	Cross section area of the flow.
A_0	$[L^2]$	Cross section area of the flow U.S. the vegetated reach.
A_t	$[L^2]$	Cross section area of the flow at the tail.
A_v	$[L^2]$	area corresponding to the vegetation.
A_1	$[L^2]$	Cross section area of the flow U.S. the transition structure.
A_3	$[L^2]$	Cross section area of the flow D.S. the transition structure.
a	$[L]$	opening height of the sluice gate.
a_0	$[LT^{-2}]$	acceleration of the flow.
B_2	$[L]$	surface width of waterway through transition structure.
B_3	$[L]$	surface width of waterway D.S. transition structure.
b	$[L]$	gate opening width.
b_f	$[L]$	bed width of flume or channel.
b_1	$[L]$	sill crest width.
c	$[L^{1/2}T^{-1}]$	Chezy's resistance coefficient.
C_c	$[1]$	coefficient of contraction.
C_d	$[1]$	coefficient of discharge.
C_{dB}	$[1]$	coefficient of discharge in the case B.
C_{df}	$[1]$	coefficient of discharge for free flow.
C_{ds}	$[1]$	coefficient of discharge for submerged flow.
C_L	$[1]$	coefficient of energy loss.
c	$[1]$	roughness parameter.
D	$[L^{-2}]$	vegetation density, stem/cm ² .
D_1	$[L^{-2}]$	high density weeds, stem/cm ² .
D_2	$[L^{-2}]$	low density weeds, stem/cm ² .

d	[L]	stem diameter.
d_{50}	[L]	grain diameter.
E	[L]	specific energy.
E_m	$[ML^{-1}T^{-2}]$	modules of elasticity of the roughness material.
E_0	[L]	specific energy upstream the vegetated length.
E_t	[L]	specific energy at the tail.
E_u	[L]	specific energy upstream the gate.
E_1	[L]	specific energy at the vena contract.
e	[L]	relative gate opening.
F_r	[1]	Froude's number.
F_{ra}	[1]	Froude's number under the gate.
F_{r0}	[1]	Froude's number U.S.the vegetated reach.
F_{r1}	[1]	Froude's number at the vena contracta.
F_{r3}	[1]	Froude's number D.S. transition structure.
g	$[LT^{-2}]$	acceleration of energy.
H	[L]	original height of the roughness elements.
H_0	[L]	total head on the upstream side of the gate.
H_u	[L]	upstream head.
h	[L]	average deflected height of the roughness elements.
h_L	[L]	head loss.
I	$[L^4]$	moment of inertia of the roughness elements.
L	[L]	gate lip length.
$L_{W\ U.S.}$	[L]	distance between weeds U.S. structure and sluice gate.
$L_{W\ D.S.}$	[L]	distance between weeds D.S. structure and sluice gate.
$L_{W.}$	[L]	distance between weeds U.S. structure and weeds D.S.
n	$[L^{-1/3}T]$	Manning's roughness coefficient.
n_{eq}	$[L^{-1/3}T]$	equivalent Manning's roughness coefficient (case of vegetation).
n_0	$[L^{-1/3}T]$	Manning's roughness coefficient in case of no vegetation.
P	[L]	wetted perimeter of cross section.
P_0	[L]	wetted perimeter of cross section without vegetation.
P_w	[L]	wetted perimeter of cross section infested by vegetation.
Q	$[L^3T^{-1}]$	discharge of the flow.

Q_A	$[L^3T^{-1}]$	discharge of the flow in the case A.
Q_B	$[L^3T^{-1}]$	discharge of the flow in the case B.
Q_s	$[L^3T^{-1}]$	discharge of the flow in the smooth case(no vegetation).
Q_w	$[L^3T^{-1}]$	discharge of the flow in case of vegetation.
q	$[L^2T^{-1}]$	discharge of the flow per unit width.
R	$[L]$	hydraulic radius.
R_b	$[L]$	bed hydraulic radius.
R_m	$[L]$	hydraulic radius in the middle of the vegetated reach.
R_N	$[1]$	Reynold's number.
R_{Na}	$[1]$	Reynold's number under the sluice gate.
R_{*N}	$[1]$	Reynold's number of particles.
r	$[L]$	spacing between the flexible elements perpendicular to the flow direction.
S	$[1]$	submergence factor.
S_r	$[1]$	relative submergence.
s_e	$[1]$	slope of the energy line.
s_0	$[1]$	bed slope of the flume.
s_w	$[1]$	water surface slope.
T_0	$[L]$	top width U.S. the vegetated reach.
V	$[LT^{-1}]$	velocity at the vena contract section.
V_a	$[LT^{-1}]$	velocity of water under the sluice gate.
V_b	$[LT^{-1}]$	velocity outside the boundary layer.
V_K	$[LT^{-1}]$	velocity at the tip of the vegetation.
V_m	$[LT^{-1}]$	velocity of water in the middle of the vegetated
V_{max}	$[LT^{-1}]$	maximum velocity.
V_1	$[LT^{-1}]$	velocity upstream the sluice gate.
V_2	$[LT^{-1}]$	velocity downstream the sluice gate.
V_*	$[LT^{-1}]$	shear velocity.
v	$[LT^{-1}]$	velocity at distance y from the channel boundary.
v_h	$[LT^{-1}]$	velocity at height h.
v_y	$[LT^{-1}]$	velocity at distance y from the bed of the channel.

x	$[L]$	spacing between the flexible elements in the flow direction.
Y	$[L]$	total length of flow.
Y_A	$[L]$	depth of flow upstream the vegetated reach in the case A.
Y_B	$[L]$	depth of flow upstream the vegetated reach in the case B.
Y_S	$[L]$	depth of flow in the smooth case.
Y_w	$[L]$	depth of flow in case of vegetation on wetted perimeter.
Y_1	$[L]$	water depth U.S. transition structure.
Y_3	$[L]$	water depth D.S. transition structure.
y	$[L]$	depth of flow above the roughness elements.
y_d	$[L]$	depth of flow downstream the sluice gate.
y_{h0}	$[L]$	the hydraulic mean depth U.S. the vegetated reach.
y_m	$[L]$	depth of flow in the middle of vegetated reach.
y_n	$[L]$	normal depth of flow.
y_0	$[L]$	depth of flow upstream the vegetated reach.
y_t	$[L]$	tail water depth.
y_u	$[L]$	depth of flow upstream the sluice gate.
y_v	$[L]$	depth of flow measured from the level of zero velocity.
y_1	$[L]$	depth of flow upstream the sluice gate.
y_2	$[L]$	depth of flow downstream the sluice gate.
z_s	$[L]$	sill height.
α	$[1]$	angle of inclination of the gate.
γ	$[ML^{-2}T^{-2}]$	specific weight of water.
δ	$[L]$	boundary layer thickness.
ΔE	$[L]$	change in energy.
Δy	$[L]$	change in depth of flow U.S. &D.S. the gate.
κ	$[1]$	universal turbulent Von Karman constant.
λ	$[1]$	resistance coefficient.
μ	$[ML^{-1}T^{-1}]$	dynamic viscosity.
ν	$[L^2T^{-1}]$	kinematic viscosity.
ρ	$[ML^{-3}]$	mass density of water.
ψ	$[ML^{-1}T^{-2}]$	total applied stress.

ψ_e [$ML^{-1}T^{-2}$] attractive shear stress.

Abbreviations:

Cm	centimeter.
D.S.	downstream.
Fig.	figure.
Ft	foot.
l	liter.
m	meter.
mm	millimeter.
s	second.
U.S.	upstream.

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