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Hydraulic Model Investigation for Using Trash Rack in Old Assiut Barrage

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الملخص :

من أجل حماية محطة كهرباء قناطر أسيوط الجديدة من انجراف الحشائش وتراكمها أمامها، تم اقتراح إنشاء نطاق شبكي على فتحات قناطر أسيوط القديمة والتي تبعد مسافة 400م أمام القناطر الجديدة. حيث تم تمثيل النطاق الشبكي في النموذج الفيزيقي باستخدام أسياخ حديد رفيعة لتمثل الطبيعة بمقياس 1 : 45. يهدف البحث إلى توضيح تأثير تراكم الحشائش المائية أمام النطاق الشبكي على مناسيب سطح المياه وتوزيع السرعات أمام وخلف قناطر أسيوط القديمة حيث تم إجراء عدد 9 إختبارات في النموذج باختلاف التصرفات المارة مع عدم وجود نطاق شبكي أو في وجود نطاق شبكي مع اختلاف نسبة تراكم الحشائش من (0%، 100%). من خلال تحليل النتائج تبين زيادة منسوب سطح المياه والفقد في الطاقة مع زيادة نسبة التراكم والتصرف المار. كما أن سرعة المياه تقل أمام وخلف النطاق الشبكي نتيجة زيادة نسبة التراكمات وأن السرعات في الأمام أكبر من السرعات في الخلف في جميع الحالات وأن سرعة المياه تزيد مع زيادة التصرفات عند نفس نسبة التراكمات.

الكلمات المفتاحية : شبك الحجز – الحشائش المائية – المخلفات الصلبة – مناسيب المياه – التراكمات.

ABSTRACT:

For the protection of the hydropower plant of the new Assiut Barrage from aquatic weeds and solid wastes, installing a rectangular steel trash rack was proposed on the vents of the old barrage which was constructed 400m upstream of the new barrage. The Trash rack was simulated in the physical model by thin steel rods with a scale of 1:45.

The research aims to define the impact of the accumulation of aquatic weeds upstream the trash rack on the water levels and the velocity distributions upstream and downstream the old barrage.

Nine tests were used with three different river flow with two conditions of new Assiut Barrage components, and three trash rack cases; without installment of trash rack, with good maintenance (0 % trash rack blockage), and with poor maintenance (100% trash rack blockage). The model investigation showed that heading up of water and the head loss increased with increasing blockage percentage and flow discharge. The velocity decreased upstream and downstream the trash rack with increasing the percentage of the blockage, the upstream water velocity is more than the downstream water velocity in all cases, and the water

velocity increased with increasing the water flow discharge at the same percentage of the trash rack blockage.

Keywords: Trash Rack; Aquatic Weeds; Solid Wastes; Water Level; Blockage.

INTRODUCTION

Across the Nile River at Assiut, 530 km downstream of Aswan, the old Assiut Barrage was constructed to satisfy the irrigation and navigation requirements. The river flows at Assiut vary between 2000 m^3/s (maximum irrigation demand) during the summer months of June/July and 350 m^3/s (minimum navigation requirement) in winter (December/January).

The New Assiut barrage and the Hydropower Plant was constructed at kilometer 529.600, 400 m downstream the old one and contains a Hydropower Plant with 4 units of bulb turbines, two spillways equipped with total 8 radial gates each 17 m wide, and a navigation lock 17 m wide and 160 m long.

The hydraulic Research Institute (HRI) construct the physical model of 1.45 scale for a river reach between Km 528.600 to kilometer 533.200 about 4.600 Km (1,000 m and 3.600 m upstream and downstream the old barrage respectively), which comprises the old and new Assiut Barrages, and the intake of Ibrahimia canal to confirm the main design features and optimize flow conditions in the vicinity of the main structures of the new barrage. The design of the new Assiut Barrage didn't take the protection of the hydropower plant of new Assiut Barrage from floating aquatic weeds and solid wastes. Therefore, the researcher proposed the construction of a trash rack on the vents of the old Assiut barrage for testing the water levels and the velocity distributions upstream and downstream the barrage.

The function of the trash rack is to blockage the floating and submerged materials and prevent it to reach the gates of the barrages and units of the hydropower plant constructed across the river, therefore the design and the research depend on previous study and researches on controlling aquatic weeds.

Hosam Ibrahim et al. [1, 2] studied installing the trash rack under the water surface by 3m such as the trash rack that used in both Esna and Naga Hammadi barrage to prevent the floating and submerged materials to reach the new barrages and protect the hydropower against the shutdown, the researcher approved that the generated hydroelectric power in Naga Hammadi was enhanced by 26%, and recommended cleaning the trash rack from time to time to prevent any increase of the water level.

Mahmoud Zayed et al. [3] investigated experimentally using the triangular V-shaped screen with a circular bar in the flow direction and approved that low head losses decreased with low screen angles for the circular bars, and reduced in comparison with the trash rack perpendicular on the flow direction.

N.R. Josiah et al. [4] carried out many tests to estimate the head losses through the trash rack on the open channel with the change of bar diameter, the spacing between bars, discharge, angle of trach rack, blockage percentage, and a new head losses formulas were estimated through trash rack of circular bars.

Sylvain Raynal et al. [5] tests experimentally the head losses and velocity fish-friendly trash racks placed in an open channel with changing parameters such as bar shapes, spacing, and angles, confirmed that the head loss coefficient is a function of the blockage ratio, the bar shape, and rack angle, and the changes of the trash angles have significant changes in velocity distribution with compared of changes of bar spacing and bar shape.

Eirik Bruvik Overgard [6] tested experimentally the head loss associated with different bar shape and spacing of the trach rack and the characteristic of the turbulent flow near the trash rack, the experiments showed that the arrangement and orientation of the bars have a bigger influence in the head loss than the shape of the bar.

Ales Hribernik [7] studied experimentally the effect of trach rack cleaning on electricity production, the analysis showed that the annual losses could be reduced significantly by applying an optimal cleaning strategy. However, an optimal strategy is difficult to predict, because of the stochastic nature of the amount of debris drifting daily in the river.

Sherif Saad et al. [8] used a physical model to investigate the aquatic weeds problems upstream new Esna Barrage on Nile River and designed a barrier with an efficient angle to protect the hydropower station from floating aquatic weeds, the study approved that the heading up was about 7cm in case of 100% barriers blockage and the velocity upstream the barriers varied from 0.1 m/s to 0.77 m/s.

Natalia et al. [9] experimented which of the examined different shapes of bars with different inclination angle and different accumulation density of weeds is the most effective for the hydroelectric power protective trash racks, the study proved that the use of cylindrical trash rack bars inclined towards the channel bottom at an angle 800 provides the most beneficial and preferred solution.

STUDIED AREAS DESCRIPTION

The study reach is located on the Nile River between Kilometer 528.600 to kilometer 533.200 downstream of High Aswan Dam (HAD) about 4.600 Km (1,000 m and 3.600 m upstream and downstream old Assiut barrage respectively). The reach contains the old Assiut Barrage, the new Assiut barrage, and the Ibrahimia canal intake, as shown in Figure 1. The Old Assiut Barrage has 800 m total length, 110 individual openings of 5 m width, and 16 m wide lock positioned on the extreme right bank. The New Assiut barrage is located 400 m downstream of the old one, and comprises three main components; a Hydropower Plant with 4 units of bulb turbines, two spillways equipped with a total of 8 radial gates each 17 m wide, and a navigation lock 17 m wide and 160 m long. The Ibrahima canal inlet is about 200 m upstream of the old barrage, on the left side of the river.

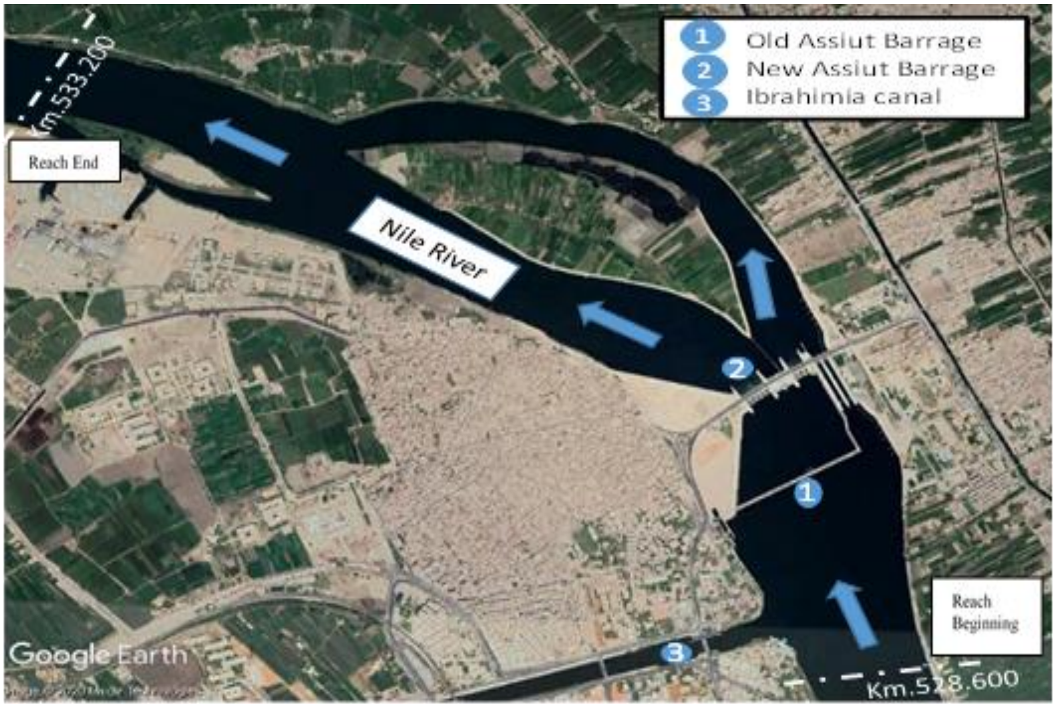

Figure 6: The Study Area

METHODOLOGY

DESIGN DATA

The 3D physical model of the New Assiut barrage was used for investigating the efficiency of the proposed trash track which will be fixed in the upstream groove of the old Assiut barrage vents during the operation of the old Barrage. The physical models were designed in the hydraulic laboratory of HRI with scale 1.45 and operated according to the field measurements by HRI.

SIMULATION OF THE TRASH RACK

The proposed trash rack for the old Assiut barrage was designed by the Canal Maintenance Research Institute comprised of rectangular steel bars with a dimension of 2cm by 5cm with equally spacing of 20cm fixed together from top and bottom with steel angle. Photo 1 shows the trash rack that is used in the model which simulates the trash rack in prototype with scale 1:45. The steel bars of the trash rack was simulated by thin steel rods with a scale of 1:45, and the solid barrage gates were made of Plexiglass sheet. Photo 2 shows the simulation of the trash rack with a 100% blockage.

Photo 1: The Trash Rack Simulates 0% Blockage By Aquatic Weeds

Photo 2: The Trash Rack Simulates 100% Blockage By Aquatic Weeds

TEST PROGRAMME AND MEASUREMENTS

3.3.1. TEST PROGRAM

The following test program was proposed for testing the efficiency of the trash rack that proposed and designed by the Channel Maintenance Research Institute. Nine tests were used without installment of trash rack, and with the installment of trash rack of 100% and 0% blocking by floating and submerged materials. the first three tests, the hydropower only was operated. In the other six tests, the flow passed only through the two components of the spillway. The trash rack was fixed in the upstream groove of the old Assiut barrage during the operation of the Barrage. There are three river flow conditions were used to test the efficiency of the trash rack. Table 1 showed the test program that was applied to investigate the efficiency of the trash rack with river flow 900, 2000, and 2900 m^3/s.

Table 6: Test Program

Test No.	Discharge (m^3/s)	Hydropower	Left Spillway	Right Spillway	Trash rack Condition
1	900	Open	Closed	Closed	No trash rack
2	900	Open	Closed	Closed	0% Blockage
3	900	Open	Closed	Closed	100% Blockage
4	2000	Closed	Open	Open	No trash rack
5	2000	Closed	Open	Open	0% Blockage
6	2000	Closed	Open	Open	100% Blockage
7	2900	Closed	Open	Open	No trash rack
8	2900	Closed	Open	Open	0% Blockage
9	2900	Closed	Open	Open	100% Blockage

3.3.2. MEASUREMENTS

During each test run the observation of the water levels were recorded in order to investigate the variation in the water levels at both upstream and downstream the old Assiut barrage. The variation in water levels were investigated in case of without installment of trash rack and with the installment of trash rack of 100% and 0% blocking by floating and submerged materials. Also, the flow velocity was measured at two cross-sections, one of them has surface water width of 787.50 m, located 112 m upstream of the old barrage, and has 16 velocity profiles, and the second cross-section has surface water width of 526.95 m, located 79 m downstream of the old barrage, and has 11 vertical velocity profiles. The flow velocities were measured at three-point depth 0.2, 0.5, and 0.8 of the water depth measured from the water surface. Figure 2 shows the location of the velocity cross-sections located upstream and downstream the old Assiut barrage.

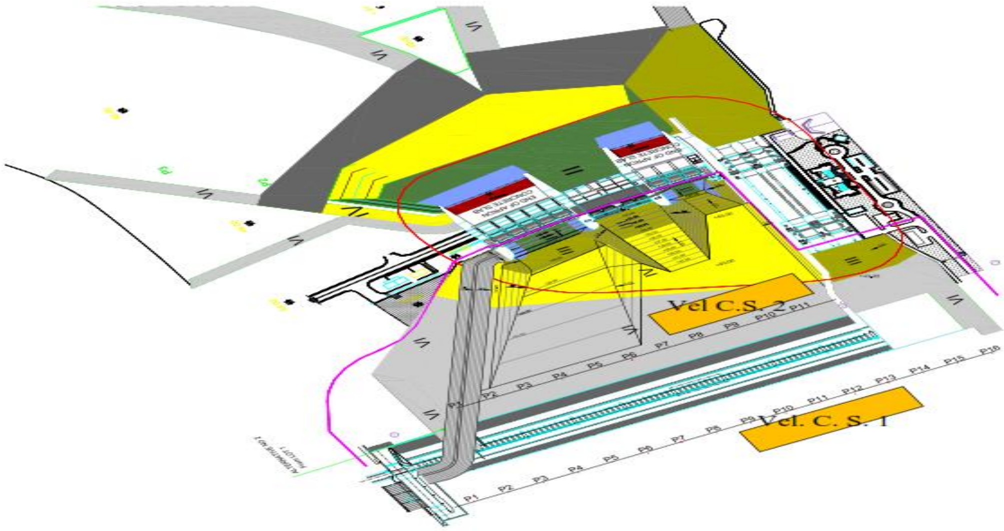

Figure 7: Location of Velocity Cross-sections U/S and D/s of old Assiut Barrage

MODEL RESULTS

Both water level variation and velocity distribution were investigated for non-installment of trash rack, 100% blocking, and 0% blocking. In the following sections, the variation in the water levels and velocity distributions were presented.

WATER LEVELS

The water level was measured upstream and downstream of the old barrage with each case at the same location of the velocities and comprised with the case of non-installment of trash rack, the measured cross section could be shown as figures 3 and 4. The obtained results as in table 2 showed that in the case of open hydropower station only with river flow 900 m3/s; the increase in water level upstream the old Assiut Barrage (heading up) due to installing the trash rack were 0.05 m and 0.10 m with 0% and 100% blockage respectively. In case of open spillways only; the heading up were 0.08 m and 0.12 m with 0% blockage for river flow 2000 and 2900 m3/s respectively. Also, the heading up upstream of the old barrage with trash rack of 100% blockage were 0.20 m and 0.35 m for river flow 2000 and 2900 m3/s respectively. The values of both heading up and head losses related to both percentage of trash rack blockage and flow discharge could be shown in figures 5 and 6 respectively. The relations between both the heading up and heading losses with discharge for 0% and 100% blockage were mentioned in equations 1,2,3, and 4. The heading up is in a direct relationship with blockage percentage and flow discharge. Also, the head losses increased with increasing the blockage of the trash rack and flow discharge then decreased after flow discharge value 1700 m^3/s.

$H_{up} = 0.0001Q - 0.02226 \quad R^2=0.97 \qquad (100\%Blockage) \qquad Eq. (1)$

$$H_{up} = 3*10^{-5}Q - 0.0162 \qquad R^2=0.98 \qquad (0\%Blockage) \qquad Eq.\ (2)$$

$$H_{loss} = -6*10^{-7}Q^2 + 0.0021Q + 2.5482 \qquad R^2=1 \qquad (0\%Blockage) \qquad Eq.\ (3)$$

$$H_{loss} = -7*10^{-7}Q^2 + 0.0021Q + 2.5027 \qquad R^2=1 \qquad (100\%Blockage) \qquad Eq.\ (4)$$

Where (H_{up}) is the water surface heading up upstream the old Assiut Barrage, and (H_{loss}) is the water surface head loss, and Q is the water flow discharge.

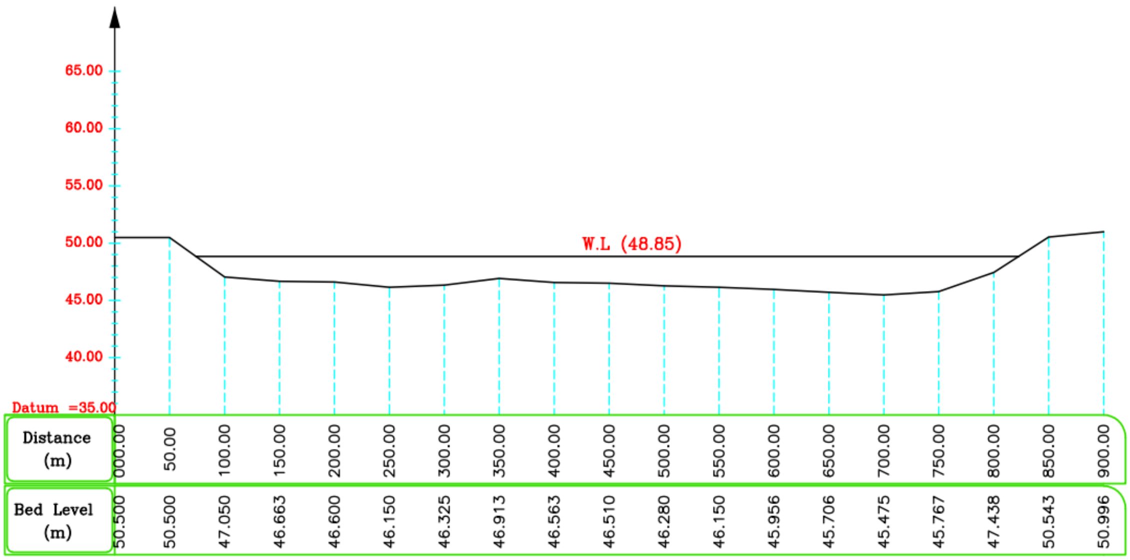

Figure 8: Cross-section upstream Old Assiut Barrage with river flow 900m^3/s

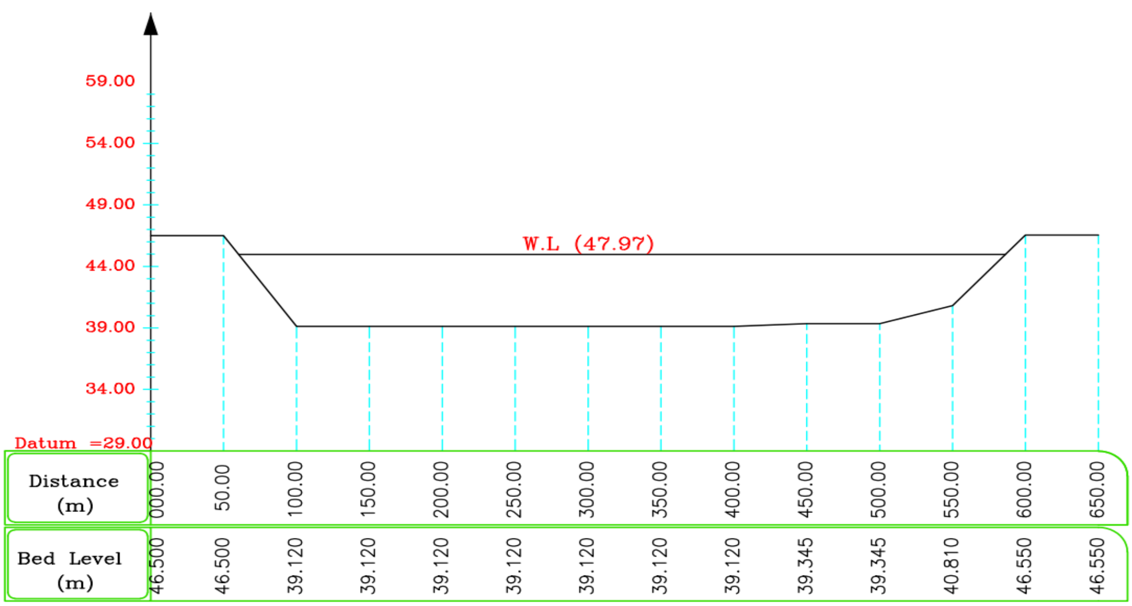

Figure 9: Cross-section Downstream Old Assiut Barrage with river flow 900m^3/s

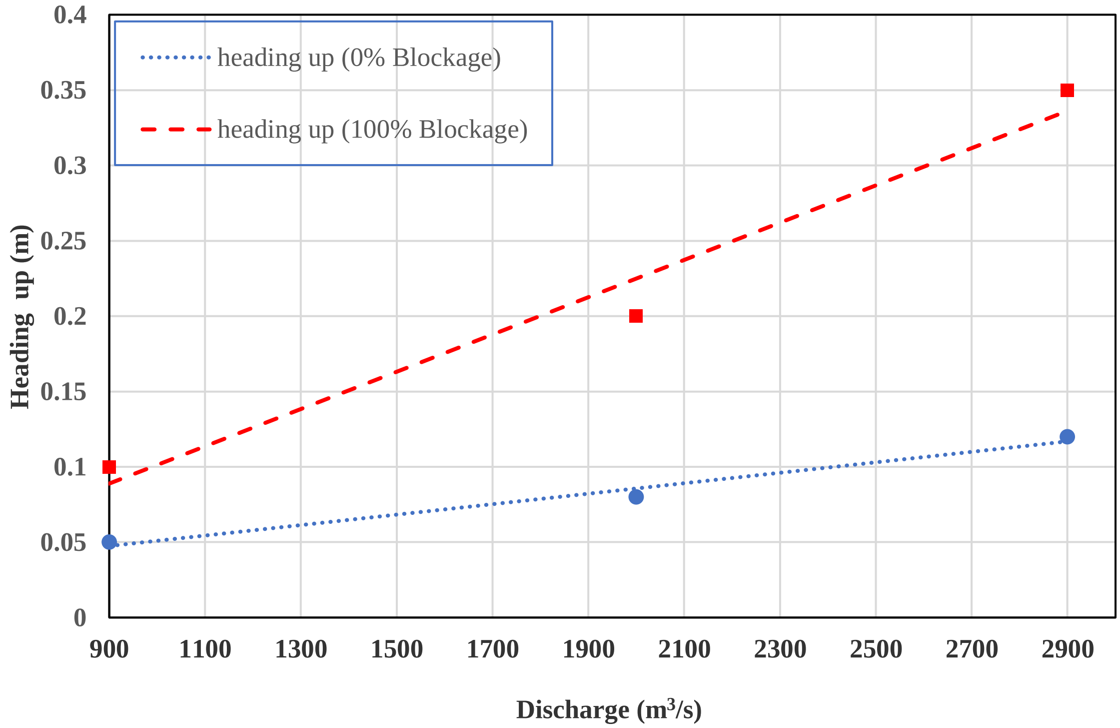

Figure 10: Water Surface Heading up Upstream Old Assiut Barrage

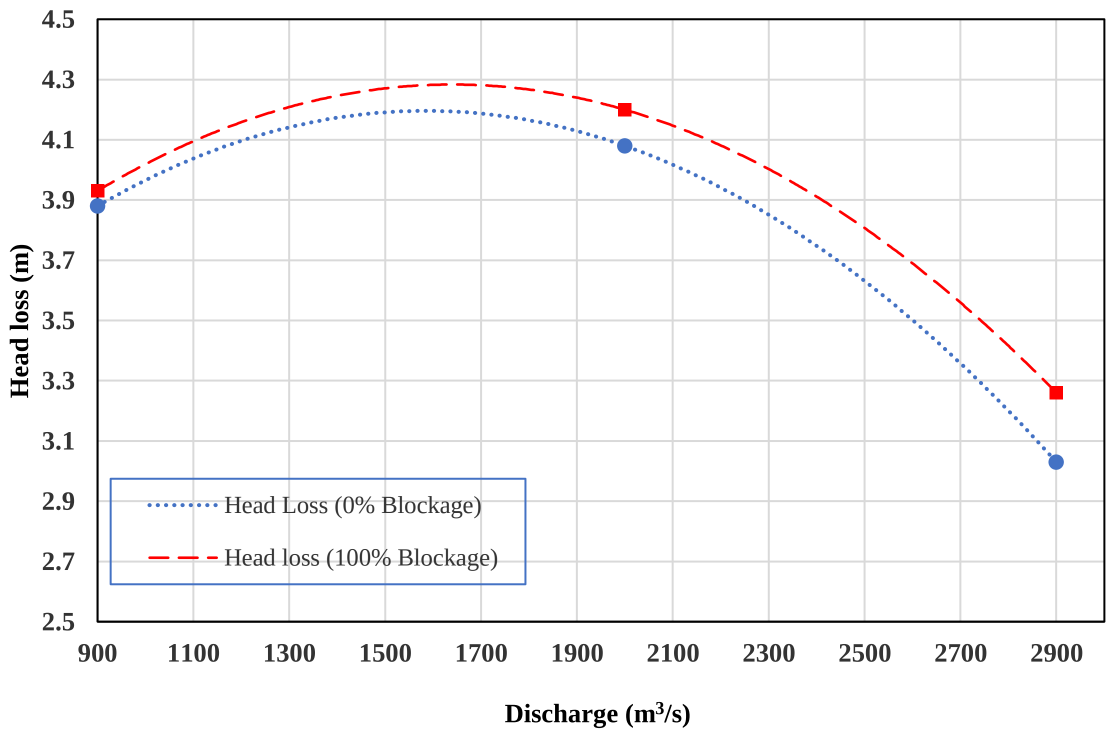

Figure 11: Water Surface Head loss

Table 7: water level, heading up, and head loss for different dischareges and blockages

Test No.	Discharge (m^3/s)	U.S.W.L	D.S.W.L	Head loss (m)	Heading up U/S Old Barrage (m)	Hydropower Condition	Spillway Condition	Trash rack Condition
1	900	48.80	44.97	3.83	0	Open	Closed	No trash rack
2	900	48.85	44.97	3.88	0.05	Open	Closed	0% Blockage
3	900	48.90	44.97	3.93	0.10	Open	Closed	100% Blockage
4	2000	50.80	46.80	4.00	0	Closed	Open	No trash rack
5	2000	50.88	46.80	4.08	0.08	Closed	Open	0% Blockage
6	2000	51.00	46.80	4.20	0.20	Closed	Open	100% Blockage
7	2900	50.80	47.89	2.91	0	Closed	Open	No trash rack
8	2900	50.92	47.89	3.03	0.12	Closed	Open	0% Blockage
9	2900	51.15	47.89	3.26	0.35	Closed	Open	100% Blockage

VELOCITY DISTRIBUTIONS

Six tests for water velocity distribution were carried out in presence of a trash rack with blockage of 0% and 100%, for each test the velocity distributions were measured and recorded at two cross-sections; one upstream and the second one downstream the old Assiut barrage. The average water velocity for all cases was recorded in table 3. The average water velocity upstream the trash rack is varied from 0.38 m/s to 0.82 m/s with 0% blockage, and 0.30 m/s to 0.76 m/s with 100% blockage. Also, The average water velocity downstream the trash rack varied from 0.25 m/s to 0.69 m/s with 0% blockage, and 0.12 m/s to 0.63 m/s with 100% blockage. The velocity decreased upstream and downstream the trash rack with increasing the percentage of the blockage, the upstream water velocity was more than the downstream water velocity in all cases, and the water velocity increased with increasing the water flow discharge at the same percentage of the trash rack blockage. Figures 7 and 8 show a sample of the results of water velocity measurements upstream and downstream the trash rack.

Table 8: Water Velocity for different dischareges and blockages

Test No.	Discharge (m^3/s)	Trash rack Condition	Average Velocity (m/s)		Hydropower Condition	Spillway Condition
			U.S.	D.S.		
2	900	0% Blockage	0.378	0.254	Open	Closed
3	900	100% Blockage	0.301	0.120	Open	Closed
5	2000	0% Blockage	0.548	0.431	Closed	Open
6	2000	100% Blockage	0.529	0.423	Closed	Open
8	2900	0% Blockage	0.820	0.693	Closed	Open
9	2900	100% Blockage	0.764	0.632	Closed	Open

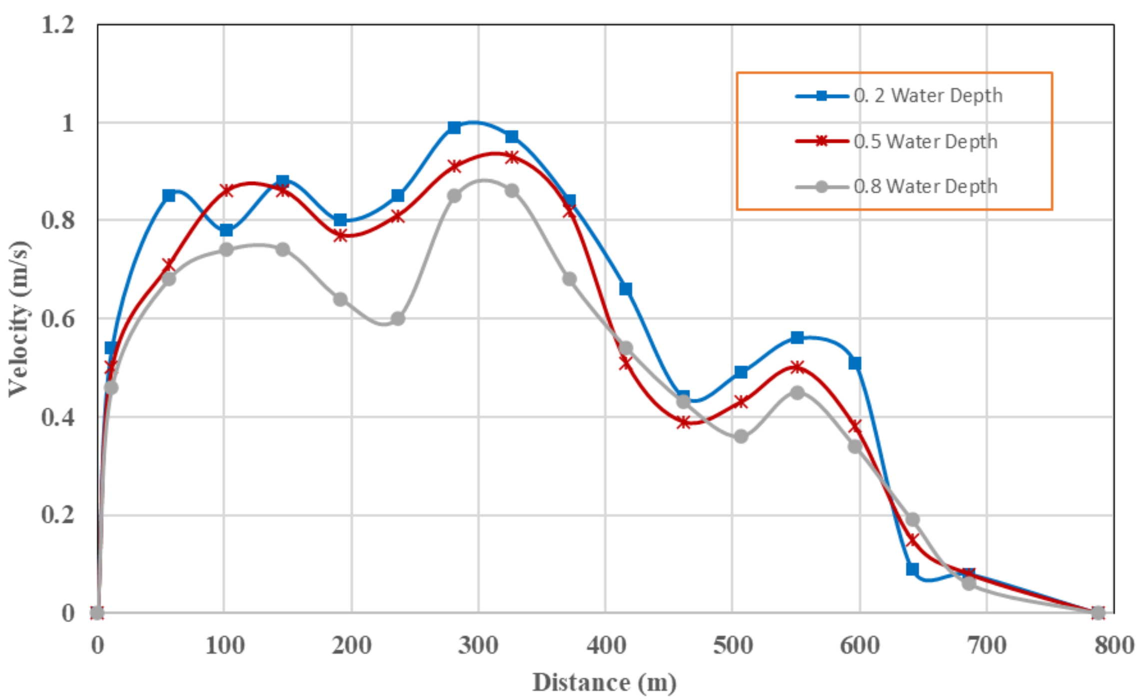

Figure 12: Velocity Distribution Upstream old Assiut Barrage with 100% trash rack blockage, Test 6

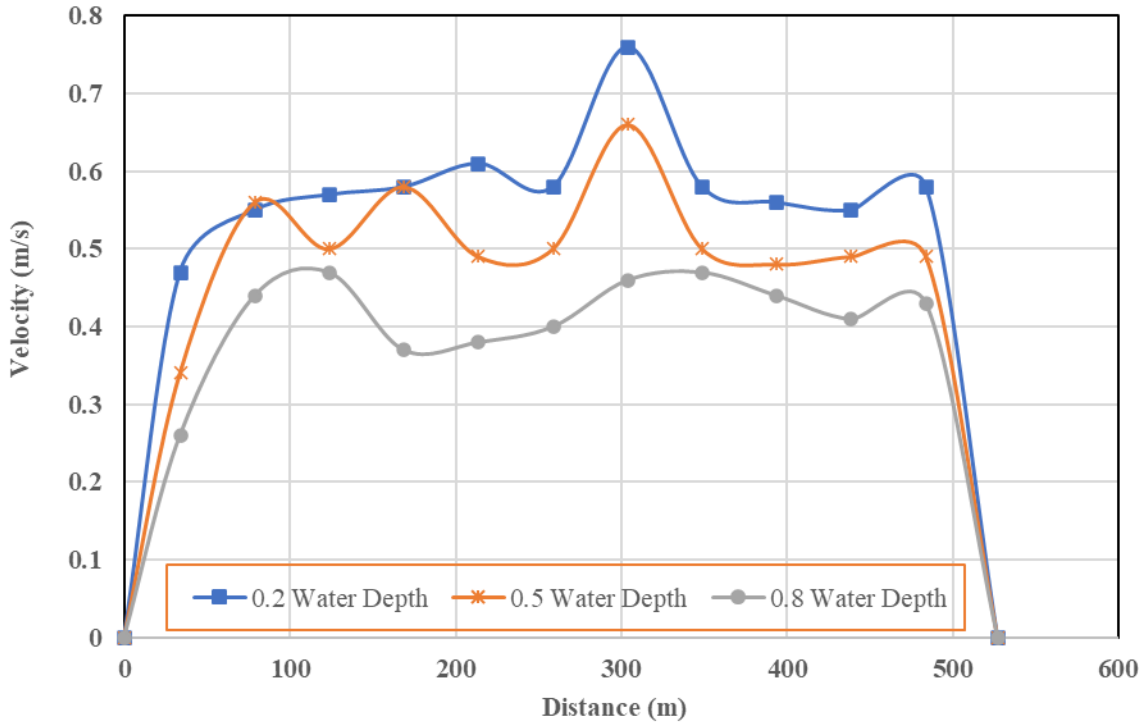

Figure 13: Velocity Distribution Downstream old Assiut Barrage with 100% trash rack blockage, Test 6

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The main conclusions that derived from the model tests are as following:

- The water levels upstream of the old Assiut barrage with the discharge of 900 m3/s through the hydropower plant only were raised up by 0.05 m and 0.10 m for 0% and 100% blockage of the trash rack, respectively.
- The water levels upstream of the old Assiut barrage with the discharge of 2000 m3/s through the two components of the spillway were raised up by 0.08 m and 0.20 m for 0% and 100% blockage of the trash rack, respectively.
- The water levels upstream of the old Assiut barrage with the discharge of 2900 m3/s through the two components of the spillway were raised up by 0.12 m and 0.35 m for 0% and 100% blockage of the trash rack, respectively.
- The heading up is in a direct relationship with blockage percentage and water flow discharge.

- The head losses increased with increasing the blockage of the trash rack and flow discharge then decreased after the flow discharge value 1700 m3/s.
- The average water velocity upstream the trash rack varied from 0.38 m/s to 0.82 m/s with 0% blockage, and 0.30 m/s to 0.76 m/s with 100% blockage.
- The average water velocity downstream the trash rack varied from 0.25 m/s to 0.69 m/s with 0% blockage, and 0.12 m/s to 0.63 m/s with 100% blockage.
- The velocity decreased upstream and downstream the trash rack with increasing the percentage of the blockage, the upstream water velocity increased than the downstream water velocity in all cases, and the water velocity increased with increasing the water flow discharge at the same percentage of the trash rack blockage.

RECOMMENDATIONS

Based on the model results for investigating the effect of the trash rack to the water levels and the velocity distributions in both upstream and downstream the old Assiut barrage; it is recommended the followings:

- Install the proposed trash rack in the vents of the old Assiut barrage in order to block the floating materials and enhance the operation of the new Assiut barrage.
- A periodic maintenance operation of the trash racks must be implemented to decrease the accumulation of aquatic weeds.
- The floating equipment could be used to clean the floating materials that stocked in the trash racks.
- Design of A trash racks must be studied carfully before installement upstream hydraulic structures.

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