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Relevant Problems of a Hydraulic Jump at Diyala Weir and the Proposed Remedy

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ABSTRACT

This study aims to analyze the Diyala weir problems and compares it with the safe limit and proposes the treatment for these problems. One of the most influencing problems in the site of weir was the formation of the hydraulic jump, it was found that the scour occurs due to the position of the hydraulic jump and the sequence depth of the jump is higher than the tail water depth. Some treatment procedures are suggested, these treatments cover this problem by presenting a suitable stilling basin as well as recommended to use a low weir at end of basin to produce a back water curve that should be increase the stage of tail water and ensuring the stability of a hydraulic jump .

المشاكل الهندسية المتعلقة بالقفزة الهيدروليكية في سدة ديالى والمعالجات المقترحة

الخلاصة

تهدف هذه الورقة الى دراسة وتحليل المشاكل الهندسية الحاصلة في سدة ديالى ومقارنة النتائج مع الحدود الأمينة للتصميم مع وضع بعض المعالجات للمشكلات القائمة حاليا . واحدة من المشكلات الموقعية المؤثرة هي خروج القفزة الهيدروليكية عن موقع حوض التسكين بعد تشكل العمق اللاحق بمنسوب أعلى من العمق المتوفر في النهر عند المؤخر وبالتالي حصول أنجراف موقعي بقيمة أعلى من الحدود المسموحة . أن من المعالجات المقترحة هو أنشاء حوض تسكين ملائم أضافة الى أنشاء هدار واطيء عند مؤخر الحوض لغرض أنتاج منحني أرتداد الغاية منه أحتواء القفزة ضمن حوض التسكين .

INTRODUCTION

There has been a weir at the site of the present Diyala weir for a long time. The original construction was in 1928; the weir is the primary means of distributing water to the entire area of the Diyala Basin. Diyala weir was designed and constructed by a Bulgarian firm to serve as an irrigation canal diversion structure. The construction of the present Diyala weir commenced in 1966 and was completed in (1969); the structure includes a road bridge and new canal headwork.

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The Diyala weir located near the region of Sidor, approximately 130 km northeast of Baghdad. Many studies and reports were submitted about it, depending on the pervious studies and reports, also from the field observations it's found that there are many problems in the Diyala weir, such as ; formation of deep scours downstream of weir, settlement of the downstream concrete blocks and damage of lip wall in front of the weir, and , damage of the chute blocks and baffle blocks at the stilling basin . The aim of this study is to analyzing the existing hydraulic jump and show its effects on a hydraulic performance of an existing weir , then proposal some treatments to solve the problems related to an existing performance .

Diyala weir consists of three major passage routes and a flushing sluiceway. Irrigation diversion exists on the right and left banks. The central section passes the remaining flow downstream toward the Tigris River. Inflow is direct from the Hemren dam. Flushing of sediments through the sluiceways is performed with limited success.

BASIC DATA AND CHARACTERISTICS OF DIYALA WEIR

The following information data were taken from Al-furat center report (1989) can be highlights the structural and hydraulics situation of structure .

a) **River-Bed Slope :** Upstream of the weir the river-bed slope is about 2 m / km while at downstream rapidly becomes more flat, about 0.1 m / km.
b) **River Discharge:** Maximum flood discharge 2500 m^3/ sec.
c) **Ultimate Canal Discharges :** The right bank: 120m^3/sec. and the left bank: 75m^3/sec.

d) Sediment Transport: Before the construction of the Hemren dam the sediments recorded about 8.5 million tons per year, after completion of Hemren dam, it is expected that all of the bed load and much of the suspended sediment will be deposited in the Hemren reservoir. Some restitution of the bed load will occur between Hemren dam and Diyala weir at the beginning but the supply will soon be exhausted and a state of bed-equilibrium with no or very little sediment transport (for average flood discharge condition) will be established.

e) Canal Head Regulator: Right bank 5 sluice gates: 1.20m width × 8.5m height for each , and left bank 3 sluice gates: 1.20m width × 8.5m height for each

f) Scour Sluices : Right bank 4 sluices gates: 2.30m width × 8.5m height for each , and left bank 3 sluices gates: 2.3m width × 8.5m height for each

g) Diversion Weir: 23 Gates : 2m width × 12m height

h) Elevations: The Weir crest el. 66.50 .a.s.l , the Scour sluice invert el. 61.50 a.s.l , the Canal head regulator invert el. 64.00 a.s.l ,Figure(1), illustrates the dimensions of Diyala weir structure with its sheet piles.

The designed discharge of the Diyala weir is not given explicitly in the document provided from previous studies and reports submitted about this structure. The report of Al-Furat Center considered the discharge of 4000 m^3/sec in calculations but dose not actually state that it is the design discharge. This leads to confusion between the design discharge of Hemren dam spillway which is designed for the peak maximum flow of 4000 m^3/sec and the design discharge of the Diyala weir.

The preferred design discharge is 2500 m^3/sec (personal communication with Ministry of Water Resources). The operation of the weir as suggested by Sogreah report in 1981 on the hydraulic model study is summarized in Table(1), for various upstream levels. At level 68.5 m the total discharge through weir and sluices is 1835 m^3/sec and is about 2660 m^3/sec at level 69.0 m. The discharge through the sluices ranges from 200 m^3/sec and 300 m^3/sec for the two levels.

FIELD OBSERVATIONS

From field visit and observation of the weir, the following remarks could be recorded that could be deduced to uncertain location of hydraulic jump :-

1- The river channel degrades at downstream.
2- Settlement of the downstream concrete blocks and damages to lip wall in front of weir as well as under sluices.
3- Damage of some of the downstream energy dissipation structures including chute blocks and baffle blocks in stilling basin. Therefore, any damage to these structures may cause scour problem at downstream of the weir because of reducing the energy dissipated in the stilling basin.

Due to the above observation problems , we concludes that the formation features and location of a hydraulic jump have a serious relation to these problems , that make this study focusing to the problem at hand by analyzing the jump , comparing with safely situations , and proposing a suitable remedy .

HYDRAULIC JUMP ANALYSIS

As a well known that a hydraulic jump is a rapid change in the depth of flow from a low stage to a high stage. Practical applications of the hydraulic jump are many ; a prevailing situation is to dissipate the excessive energy in water that flowing downstream a hydraulic structures and thus prevent scouring downstream from the structures.

Several basic characteristics of the hydraulic jump in a horizontal rectangular channel are to be discussed below can be found in different related text books , these characteristics presented with the form of computing formulas such as ; **Energy loss** ; it is a difference between the residual specific energy at downstream to the specific energy in section before the jump (i.e ΔE=E2-E1) , **Efficiency of the jump**; it is a relative ratio between the downstream specific energy and upstream one before jump , (i.e. E2/E1) , **Height of the jump (h_j) ;** it is a difference between the sequent and initial depths , and the **Length of the jump (L_j)** ; where it is the distance measured from the front face of the jump to a point on the surface immediately downstream from the roller. The hydraulic jump used for energy dissipation is usually confined partly or entirely to a channel reach that is known as the (stilling basin).

It is assumed that the tail water has a certain fixed position, whether its depth $\mathbf{y_2}'$ is equal to, less than, or greater than the sequent depth $\mathbf{y_2}$. In most practical problems, however, the tail water fluctuates, owing to changes in discharge of flow in the channel. In such cases, a tail water rating curve is usually available to show the relation between the tail water stage , $\mathbf{y_2}'$, and the discharge Q. in a similar way, a jump rating curve may be constructed to show the relation between the sequent depth , $\mathbf{y_2}$, and the discharge Q . Because of the difference in the relative positions of the two rating curves, (Leliavsky, 1965) has suggested that the design may be considered according to five different classes of conditions as shown in Figure (2) .

STILLING BASIN OF GENERALIZED DESIGN

Stated in the aforementioned section, all types of hydraulic jump must be encountered by stilling basins. The generalized designs for the basins are often necessary for economy and to meet specific requirements. The basin thus designed is usually provided with special appurtenances, including chute blocks, sills, and baffle blocks.

The chute blocks are used to form a serried device at the entrance to the stilling basin. Their function is to furrow the incoming jet and lift a portion of flow floor, producing a shorter length of jump than would be possible without them. These blocks also tend to stabilize the jump and thus to improve its performance.

The sill, either dentate or solid, is usually provided at the end of the stilling basin. Its function is to reduce further the length of the jump and to control scour. For large basins that are designed for high incoming velocities, the sill is usually dentate to perform the additional function of diffusing the residual portion of the high-velocity jet that may reach the end of the basin.

Baffle blocks are blocks placed in intermediate positions across the basin floor. Their function is to dissipate energy mostly by impact action. The baffle blocks are very useful in small structures with low incoming velocities. They are unsuitable, however, where high velocities make cavitations possible. There are many generalized designs of stilling basin that use a hydraulic jump as the means of energy dissipation . The widely and commonly used in applications are those which recommended by the USBR such that ; **the Saint Anthony Falls (SAF) Basin , the USBR Basin II , the USBR Basin IV.** The two of these will be applied to study problem at hand .

RELATED PREVIOUS STUDY

A previous investigations and researches (1),(6),(10), were made in order to solve and analyze the related problem . The studies carried out analysis of downstream channel scouring and the treatments presentation about the problem were concluded that , the elevation of the downstream river channel is depressed due to scouring during periods of heavy flow and subsequent poorly distributed flow. Excessive downstream sand and gravel mining has aggravated the downstream channel depression. In addition, the lake of sediment in the water passing through the weir makes replenishment from natural sources unlikely.

After calculation of the water surface profiles downstream of the weir, the sequent depths of the hydraulic jump are also calculated together with the tail water levels. The analysis of above concepts shows that periodic repair of the damage to the existing stilling basin and apron is not a solution since the downstream scour problem is not a result of the damages to the stilling basin, but that functioning is completely prevented by the low tail water. Therefore, a low weir, 2 m high, with crest at elevation at 63.5 a.s.l. was selected for creating a stable hydraulic jump in the existing apron and to construct a second stilling basin downstream of the weir, so that presented tail water level is sufficient within the lower basin.

HYDRAULIC JUMP ANALYSIS

One of the most important reasons which cause weir failure is presence of deep scour downstream of aprons due to heavy regression and formation of hydraulic jump outside the floor which is limited for it.

Therefore, the hydraulic jump in Diyala weir was analyzed and the initial and sequent depths were calculated by using the following equations:-

$\mathbf{L_j} = 5.72y_2$, $\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1+8Fr_1^{\ 2}} - 1\right)$, $Fr_1 = \frac{q}{\sqrt{9.81{y_1}^3}}$, $y_1 = T.E.L. - \frac{q^2}{19.62y_1}$,

T.E.L = C.L.W – D/S B.L + H_e , $H_e = H_w + V^2 / 2g$, $V = q / H_w$, $q = Q / B$
where: L_j, y_1, y_2, Fr: as defined previously.
q : intensity of discharge (m^3/s/m).
T.E.L.: total energy line.
D/S B.L: downstream bed level.
H_e: Energy head above the crest (m).
Q: discharge of structure (m^3/s).
V: velocity (m/s).
H_w : depth of water above the crest (m).

The results of hydraulic jump are illustrated in Table(1) and after compared them with the types of hydraulic jump, it was found that at the maximum discharge , the type of hydraulic jump in Diyala weir is ***oscillating type***. Also, it was found that the sequent depth of the hydraulic jump is more than the tail water depth, or the jump rating curve is always at a higher stage than the tail water rating curve. This means that the hydraulic jump will form at a certain place of downstream , from this feature of jump it would be expected to encounter scouring problem downstream.

The Hemrin reservoir constructed on Diyala weir works as a setting basin, so that the sediment particles carried by the water are deposited in the reservoir and the release water becomes clear of sediment. Thus, the capacity of river to convey the sediment, will increase and the scour mechanism may be noticed. When the sediment – laden water reaches the Diyala weir, the deposition process starts on upstream side, This may cause an appreciable increase in the river bed lend, whereas a significant decreasing in the bed level at downstream side of Diyala weir occurs. The slope of the river bed increases due to the increasing of scouring process at downstream side and consequently, the flow velocity is also increased. Therefore, the hydraulic jump proceeds out of the existing stilling basin causing serious problems. For any water level at upstream side associated with a certain gate opening in the weir, the hydraulic jump regresses towards the downstream further distance from that which has been designed. This regression occurs because the hydraulic jump, in fact, is connected to water level and the decrease in bed level gradually for the weir discharge because the decrease in bed also leads to regress in hydraulic energy dissipaters area and finally occurrence of erosion, scour, and moving concrete blocks.

TREATMENT SUGGESTED OF HYDRAULIC JUMP PROBLEM

As mentioned previously that one of serious problem in the Diyala weir is the hydraulic jump: which has , as found from analyzing the extracted data that the rating curve higher than the tail water rating curve, therefore, the hydraulic jump is formed beyond the stilling basin. The proposed solution to this problem is to create a stable hydraulic jump within the limited stilling basin. This can be done by:

a- When we used the proposed stilling basin type (U.S.B.R Π) or type (S.A.F) and lowering the bed of the stilling basin from (61.5m to 59.0m) a.s.l. The calculations and the checking of the hydraulic rating curve are less than the tail water rating curve as shown in Tables (2) and Table (3).

b- Construct a low weir, 1.25m high, with crest at 62.75m a.s.l. this weir make the tail water level always is higher than the sequent depth of the hydraulic jump (the water level thus created are sufficient to contain the hydraulic jump in the stilling basin).

CONCLUSIONS

From the hydraulic analysis of Diyala weir, it's found that the failure corresponds to position of the hydraulic jump due to the variation occurring in the bed of the river. Scouring mechanism is thoughtfully influenced by the operation of the Hemren dam.

Also, its found if the bed level of stilling basin must be lowered to 59.0 and using stilling basin type (U.S.B.R∏) or type (S.A.F) the tail water level becomes higher than the sequent depth of the hydraulic jump and the process of scouring is stopped.

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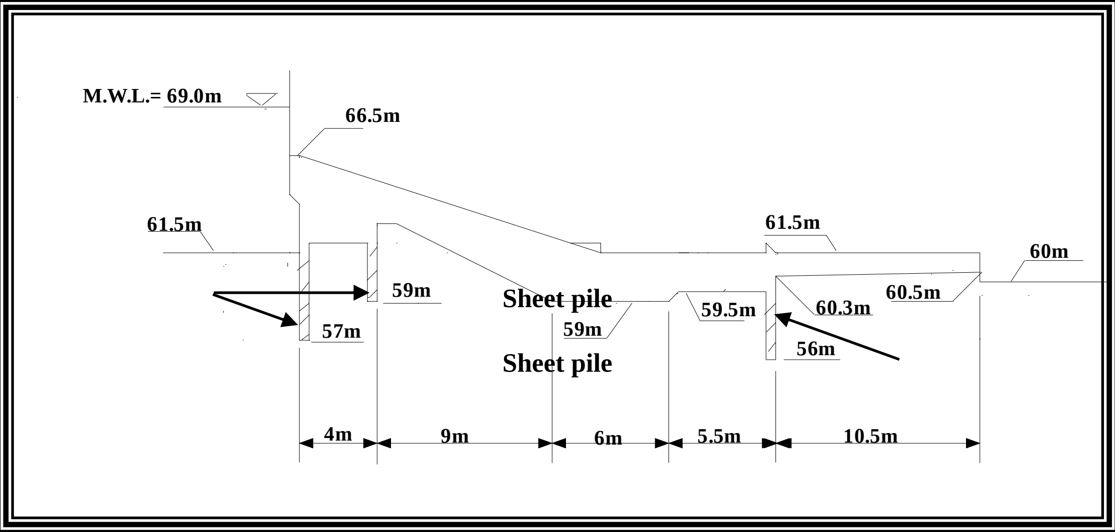
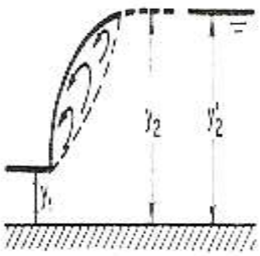
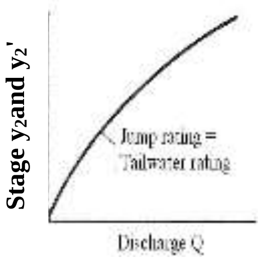


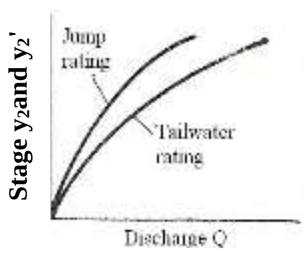
Figure(1) Dimensions of Diyala Weir Structure (modified from report of Consulting Engineering Bureau / Baghdad. Univ. 2005).

y_2: sequent depth
y_2': tailwater depth

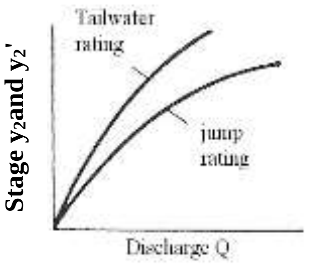
Case 1 Case 2

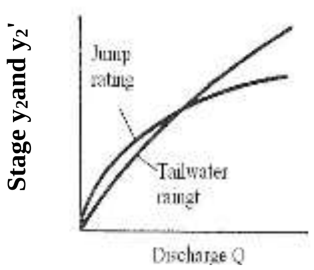






Case 3 Csea4 Case 5





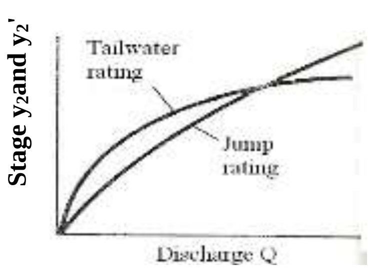


Figure 2: Classification of tailwater conditions for the design of scour-protection works (After Chow, 1959)

Table (1) Hydraulic jump calculations.

Q (m^3/s)	q ($m^3/s/m$)	H (m)	V (m/s)	H_a (m)	H_e (m)	E_1 (m)	y_1 (m)	V_1 (m/s)	F_{r1}	y_2 (m)	$y_{2\ level}$ (m.a.s.l)	Tail water level (m.a.s.l)
192	0.696	1.0	0696	0.025	1.025	6.025	0.065	10.708	13.41	1.20	62.70	61.80
900	3.261	1.5	2.174	0.241	1.741	6.741	0.29	11.245	6.66	2.6	64.10	62.80
1656	6.0	2.0	3.0	0.459	2.459	7.459	0.52	11.54	5.11	3.51	65.0	63.60
2368	8.58	2.5	3.432	0.60	3.10	8.1	0.713	12.034	4.55	4.25	65.75	64.0
3178	11.514	3.0	3.808	0.74	3.74	8.74	0.93	12.38	4.1	4.95	66.45	64.60

Table (2) Hydraulic jump calculations with using stilling basin type (Π) and lowering the bed to 59m a.s.l.

Q (m^3/s)	q ($m^3/s/m$)	H (m)	V (m/s)	H_a (m)	H_e (m)	E_1 (m)	y_1 (m)	V_1 (m/s)	F_{r1}	y_2 (m)	$y_{2\ level}$ (m.a.s.l)	Tail water level (m.a.s.l)
192	0.696	1.0	0696	0.025	1.025	8.525	0.054	12.89	17.71	1.326	60.33	61.80
900	3.261	1.5	2.174	0.241	1.741	9.241	0.246	13.26	8.536	2.85	61.85	62.80
1656	6.0	2.0	3.0	0.459	2.459	9.959	0.439	13.67	6.58	3.872	62.872	63.60
2368	8.58	2.5	3.432	0.60	3.10	10.61	0.613	14.0	5.71	4.653	63.653	64.0
3178	11.514	3.0	3.808	0.74	3.74	11.24	0.805	14.303	5.09	5.406	64.40	64.40

Table (3) Hydraulic jump calculations with using stilling basin type (S.A.F.) and lowering the bed to 59m a.s.l.

Q (m^3/s)	q ($m^3/s/m$)	H (m)	V (m/s)	H_a (m)	H_e (m)	E_1 (m)	y_1 (m)	V_1 (m/s)	F_{r1}	y_2 (m)	$y_{2\ level}$ (m.a.s.l)	Tail water level (m.a.s.l)
192	0.696	1.0	0696	0.025	1.025	8.525	0.054	12.89	17.71	1.326	60.33	60.806
900	3.261	1.5	2.174	0.241	1.741	9.241	0.246	13.26	8.536	2.85	61.85	62.426
1656	6.0	2.0	3.0	0.459	2.459	9.959	0.439	13.67	6.58	3.872	62.872	63.291
2368	8.58	2.5	3.432	0.60	3.10	10.61	0.613	14.0	5.71	4.653	63.653	63.955
3178	11.514	3.0	3.808	0.74	3.74	11.24	0.805	14.303	5.09	5.406	64.406	64.78