

***Water Resources and Surveying Engineering***

**Performance Evaluation of Pump Station of Main Outfall Drain in AL Nassiriyah City**

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**ABSTRACT**

The Main Outfall drain pumping station in Nassiriyah is an important part in operation system of the Main Outfall Drain (MOD) where it reduces the water levels in the U/S area of its and converted through Syphon freely under the Euphrates, its consists of several parts: U/S Basin, Station Building which contains 12 pumps, and Head Basin with Syphon, This station suffers from high levels especially in D/S area due to the current situation which is represented by establishing of dyke with pipes on MOD which located at 24 km from D/S of pumping station and Al-Khamisiyah Canal which located at 2.3 km from the U/S of dyke which feeds (Al Hammar Marsh) during drought season, several scenarios were adopted in order to explore the hydraulic effect of the current situation on the water levels and the performance of the syphon pumping system. The hydraulic effect of current situation causes an increase in D/S levels from 0.75 to 1 m, 0.37 to 0.6 m in operating (1,2) pumps, and the highest lack of the performance equal to 9.87%, 5.58%, 3.62%, 2.62 % in operating (1,2,3,4) pumps respectively with designed head and 8.55%, 5.40%, 3.11%, 1.8% with non- designed head.

**Keywords:** Main Outfall Drain, AL Nassiriyah City, HEC-RAS, Pumping Station

**تقييم اداء محطة ضخ مبزل المصب العام في مدينة الناصرية**

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**الخلاصة**

تعد محطة ضخ المصب العام في الناصرية جزءاً مهماً في نظام تشغيل مبزل المصب العام . حيث تقوم بخفض منسوب المياه في منطقة مقدمها وتحويلها عبر سيفون بحرية تحت الفرات ، وتتكون من عدة أجزاء: حوض المقدم ، بناية المحطة الذي يحتوي على 12 مضخة ، والحوض الرئيسي مع السيفون ، تعاني هذه المحطة من ارتفاع مناسيبها خاصة في منطقة المؤخر بسبب الوضع الحالي الذي يتمثل في إنشاء سدة مع أنابيب على مبزل المصب العام والتي تقع على بعد 24 كم من مؤخر محطة الضخ

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وقناة الخميسية التي تقع على بعد 2.3 كم من مقدم السدة الذي يغذي (هور الحمار) خلال موسم الجفاف, تم اعتماد العديد من السيناريوهات لاستكشاف التأثير الهيدروليكي للوضع الحالي على مناسيب المياه وأداء نظام ضخ السيوفون. يتسبب التأثير الهيدروليكي للوضع الحالي في زيادة مناسيب المؤخر من 0.75 إلى 1 متر، ومن 0.37 إلى 0.6 متر في تشغيل (1،2) مضخات و اكبر نقص في الأداء يساوي 9.87%، 5.58%، 3.62%، 2.62% في تشغيل (1،2،3،4) مضخات على التوالي مع المناسيب التصميمية و 8.55%، 5.40%، 3.11%، 1.8% مع المناسيب الغير تصميمية .

الكلمات الرئيسية: مبزل المصب العام, مدينة الناصرية, HEC-RAS, محطة الضخ

## 1. INTRODUCTION

The starting of the work in the Main Outfall Drain Project (parts thereof) in the 1950 and continued until 1992, which was not completed at that time. A number of these parts remained unfinished until 2009, where the project was completed with a design capacity of 220 m<sup>3</sup> /sec pumped through the pumping station . The purpose of establishing Main Outfall Drain(MOD) for the reclamation of agricultural land between the Tigris and Euphrates rivers. MOD total length is 565 km, 160 km within the boundaries of the province of Thi-Qar which extends between stations 83 km at Basra Province to 243km at Diwaniyah Province. MOD is fed by main drains with a total length of 434 km within the province of Thi –Qar. The main drains which feed MOD are ALGharaf ALKabeer, Fourat Asharqi and Sharaq ALGharaf (**Directorate of the Main Drain in Thi- Qar, 2019**). As a result of the intersection between MOD and Euphrates River a syphon is required, where the water of MOD will flow below Euphrates River. In order to get the required head of water to flow freely with the syphon the establishment of pumping system is essential. The pumping system consists of several parts, the first part contains a basin which is connected to the pumping station, the second part contains the station building which contains 12 pumps and other systems, the last part (downstream part) which includes concrete basin which work to dissipate the water energy and raise the water level to allowable levels to pass freely through the Syphon.

The objective of this study is to investigate the effect of the current situation on pumping station by using HEC-RAS software version 5.03, several scenarios were adopted in order to explore the hydraulic effect of the current situations on the water levels and the performance of the syphon pumping system. The effect of the current situation will generate backwater curve that may cause a negative effect on the performance of pumping system .

The current situation which is represented by establishing of a dyke with pipes on MOD which located at 24 km where the dyke is to raise the levels of water in order to convert part of the MOD discharge towards Al-Khamisiyah Canal which located at 2.3 km at the U/S of the dyke, this canal is used to feed Al Hammar Marsh during drought season. Although there are major rivers such as the Euphrates River, which enters the marsh and has two major channels ,one of these is connected with the Tigris River and the other is joined with the Shatt al-Arab (**Al Thamiry, et al., 2013**).

The literatures were reviewed through this study, which includes:

(**Consulting Engineering Bureau, 2010**) provided a comprehensive study of the Main Outfall Drain, this study is very important because of the lack of studies related to Main Outfall Drain, which contains the information of drains that fall in the Main Outfall Drain, the state of Main Outfall Drain in terms of discharges, and the possibility of using the technologies for treatment drain water for industrial purposes.

(**Dahham, I.A., 2017**), was provided study for the type of centrifugal pumps of a wastewater where an integrated pumping system was produced and thus it produced an integrated engine . The system scenarios were used in this study represented by change the speed of pump rotation and using the specific energy to estimate the performance of the pumps and to know the cost of the pumping



system was suggested, the results were shown possibility of production of lack energy equal to 30% in high speed due to reduce the speed of pump by 10%.

(**Abdulatif and Rhmaan, 2017**), this study was conducted which included hydraulic model by using HEC RAS software and a laboratory experiment for a semicircle crest with diameter of (4 cm) to obtain a relationship between discharge and head. The study also included dimensional analysis to estimate the value  $(R/H)$ , which find equal to the value of the coefficient of weir (cd) The laboratory results were compared with the HEC RAS one-dimensional program, which gave good results. The HEC RAS was used in this study to find relationship between discharge and head and profiles of water-surface with condition of free flow.

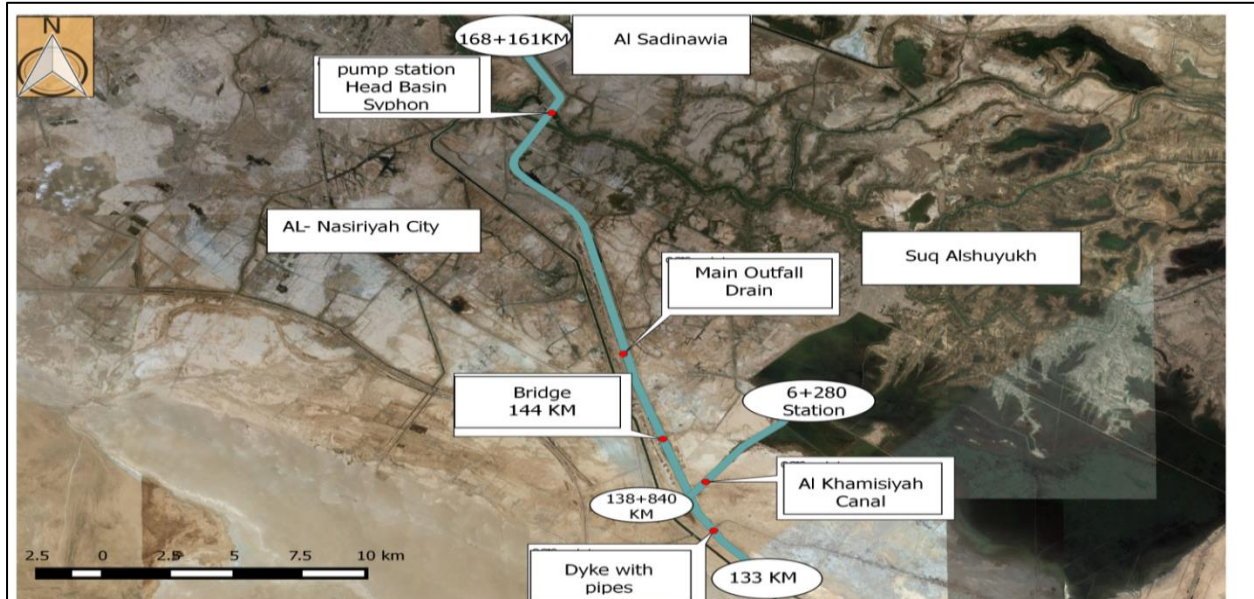
(**Mustafa et al., 2017**), prepared a report by using HEC RAS software to calculate the water quality and transfer of sediment for Euphrates River from D/S of Hadith dam (U/S of this study) to Heet station (D/S of this study), this study also including on calibration and verification process to find the Manning Coefficient equal to (0.033), and they found mass accumulated of sediment (237.38 ton per day) was bigger than the sediment value of study in 2010 which equal to (165 ton per day). Although the sediment load value in the same study at the heart city station equal to (551.76 ton per day) which was considered less than the value of sediment in a study in 1988 which that equal  $(189.041 \times 10^3 \text{ ton per day})$ , because rising in the discharge that was received in that region.

(**Al Khuzaiya, et al., 2018**), this study was submitted to estimate the roughness coefficient of Manning for a part of the Euphrates River by using HEC RAS software within the city of Al Samawah. A hydraulic model for this study area was constructed and calibrated by using RMSE equation for values of the Manning's coefficient from 0.025 to 0.04 where the results gave the lowest ratio of error when  $n = 0.04$ .

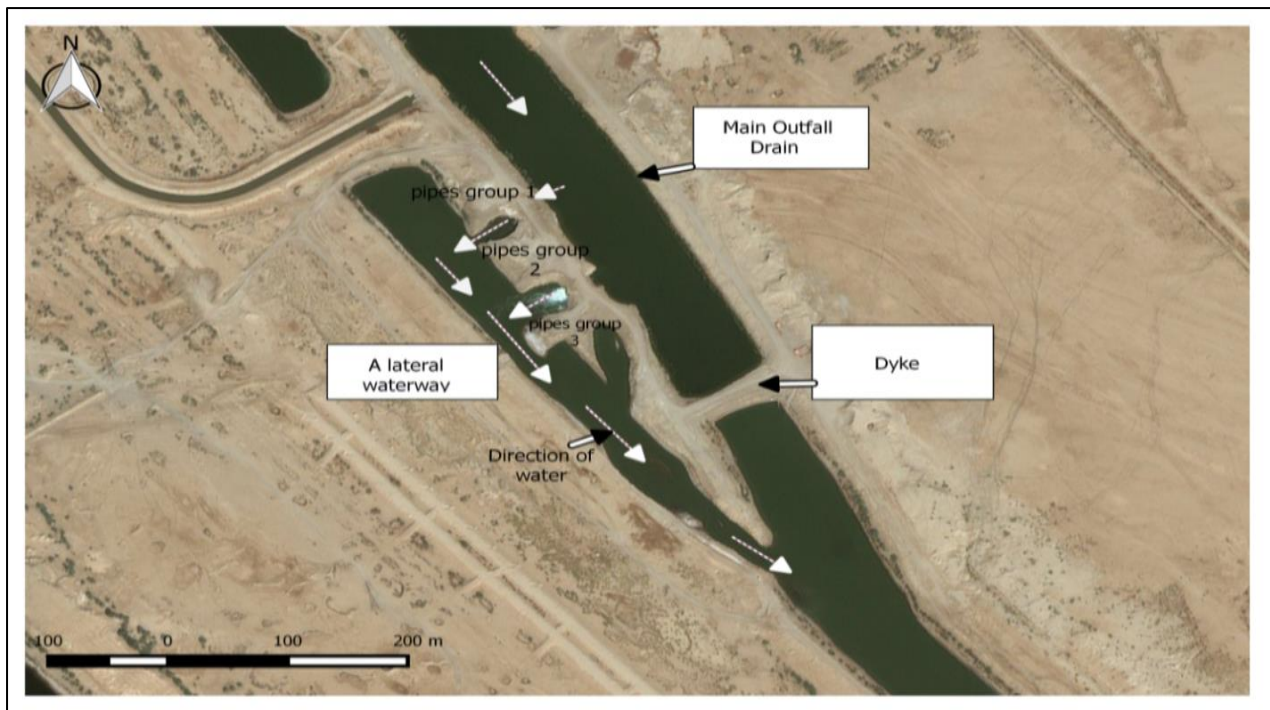
(**Mohammed, et al., 2018**), The study is conducted to calculate the manning coefficient by using the HEC RAS software at the Gharraf River in the unsteady and steady flow conditions for the area between AL Kut (U/S of the study) and AL Hay Regulator (D/S of the study), the calibration process was done to the manning coefficient which is equal to 0.026 and the verification process which gave a good results, the field works of this study included the field investigations of cross sections and hydrological by using ACDP device. The result of this study is showing The effect of the AL Hay Regulator on Al Gharaf Regulator by using several scenarios for the openings of gates.

## 2. DESCRIPTION OF THE MOD REACH IN THE STUDY AREA

The MOD extends in this study area from the Al Sadinawia Bridge area which located at Latitude:  $31^{\circ}2'12.86''\text{N}$ , Longitude:  $46^{\circ}19'17.66''\text{E}$  (East of the AL Nasiriyah City) to the U/S of pumping station located at Latitude:  $30^{\circ}58'29.09''\text{N}$ , Longitude:  $46^{\circ}20'3.82''\text{E}$ , where the pumping station is connected with the U/S Basin and with Head Basin which it is connecting with Syphon located at Latitude:  $30^{\circ}58'8.76''\text{N}$ , Longitude:  $46^{\circ}20'3.82''\text{E}$ , so, the reach continues until to junction where it is joined with Al-Khamisiyah Canal as shown **Fig. 1**. The dyke with pipes are located at Latitude:  $30^{\circ}46'18.11''\text{N}$ , Longitude:  $46^{\circ}24'5.11''\text{E}$  on MOD, where water is discharged towards Basra Governorate by 12 pipes as shown **Fig. 2**. The effect of the current situation started on December 2009, noting that pumping station entered the work in early December of 2008. Details of the structures within the study area are provided by (**Directorate of the Main Drain in Thi-Qar, 2019**) and presented in **Tables 1, 2, 3 and 4**



**Figure 1.** The layout of MOD in the study area by Quantum Geographic Information System.



**Figure 2.** Earthen dyke of MOD with buried pipes by Quantum Geographic Information System.



**Table 1.** Design details for pumps .

Number of pumps	Type	Consumption power ( mw)	equation of loss ( m)	Diameter (mm)	speed rotation (rpm)
12	horizontal axial flow	1.183-0.800	Q2 * 0.00175	2250	200

**Table 2.** Design details for Head Basin.

Length (m)	Width ( m)	Depth (m)	Bed level ( m.a.s.l.)
100	85	12.47	.-3.47

**Table 3.** Design details of syphon.

Length (m)	Number of Openings	flow velocity (m/sec)	Discharge (m3/sec)	bed level U/S (m.a.s.l.)	bed level mid (m.a.s.l.)	bed level D/S (m.a.s.l.)
320	3	3.3	200	-3.37	-12.45	-0.58

**Table 4.** Details of dyke with pipes

Level of Crest (m.a.s.l.)	Width of top (m)	Side Slope	Length (m)
(5.62-6)	12	1 V : 3.5 H	130

**3. SIMULATION OF MODEL**

The well-known software HEC -RAS was used in the simulation process, the equations were solved in HEC -RAS software are continuity equation as Eq. (1), momentum equation as Eq. (2) for unsteady state and the energy equation as Eq. (3) for steady state

$$q = \left( \frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} \right) \tag{1}$$

$$\left( \frac{\partial Q}{\partial t} + \frac{\partial VQ}{\partial x} \right) + (gA) \left( \frac{\partial Z}{\partial x} + S + Sf \right) = 0 \tag{2}$$

- q : flow of stream per unit distance
- A: area of cross section for channel
- V : averaged velocity of stream in channel
- S: slope of bed
- Sf: slope of energy
- t : time

$$\left( Y_1 + \frac{\alpha_1 V_1^2}{2g} + Z_1 \right) = \left( Y_2 + \frac{\alpha_2 V_2^2}{2g} + Z_2 \right) + (hl) \tag{3}$$

- Z<sub>1</sub>,Z<sub>2</sub>: bed level of channel
- Y<sub>1</sub>,Y<sub>2</sub> : water depth in channel
- α<sub>1</sub>,α<sub>2</sub> : coefficient of velocity
- V<sub>1</sub>,V<sub>2</sub> : averaged velocity of stream in channel

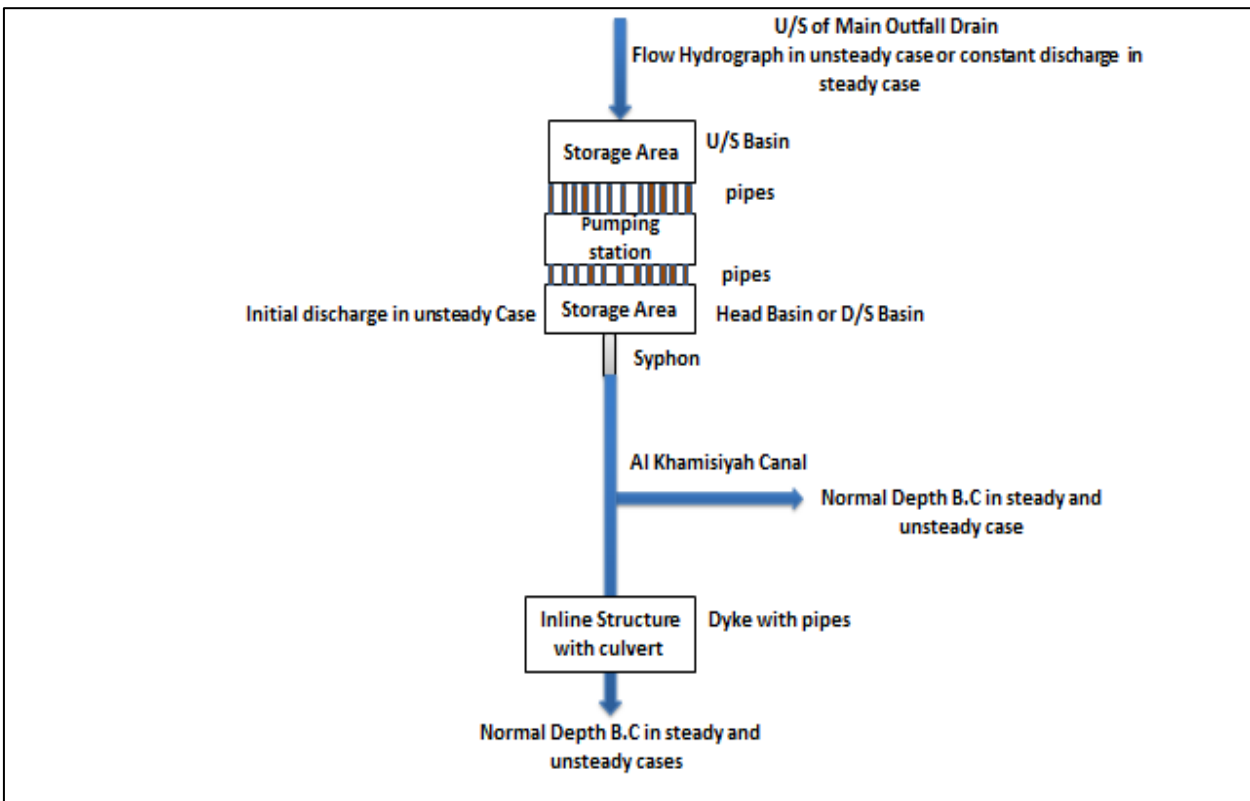


g : acceleration  
 hl : total of loss

The geometric data are the cross sections of Main Outfall Drain 200 meters apart that provided by (Directorate of the Main Drain in Thi- Qar,2019) which implemented by (the General Authority for Surveying of the Ministry of Water Resources,2012). Normal depth was assigned at the end of the MOD after the dyke and the end of the Khamisiyah Canal as boundary conditions in the downstream. As for the boundary conditions in the upstream, the flow hydrograph was used in the unsteady state or constant discharge in the steady state as shown in the Table 5 and Figure 3 which shows a schematic diagram of the MOD with all structures that is simulated in the one dimensional hydraulic model with all boundary conditions .

**Table 5** The values of boundary condition in simulation model provided by ( Directorate of the Main Drain in Thi- Qar,2019).

Type of boundary condition	Location of boundary condition	The value
Normal depth	D/S of M.O.D after dyke	0.0000265
Normal depth	D/S of Khamisiyah Canal	0.00007
Flow hydrograph	U/S of M.O.D	Daily operating data
Constant discharge	U/S of M.O.D and Khamisiyah Canal	



**Figure 3.** Schematic diagram of Main Outfall Drain with boundary conditions considered in the simulation.



The simulated model was run for two cases, the steady and the unsteady states. The unsteady state was used to determine the effect of the variables after 2009 on the levels and performance of the pumping system in AL Nasiriyah by using a several scenarios. As for the operation of the software in the steady state for the Manning coefficient, which is an important factor in any study in the open channel field, where it was found to be 0.044, where the calibration and verification were performed by using available recorded data from the years 2015 to 2018. The available data before 2015 is not used because of the change in the study area which is represented by the opening of the emergency canal which located at U/S of the dyke, where the data of the this canal was not recorded.

#### 4. IMPLEMENTATION OF SCENARIOS

The reason for the implementation of the scenarios is to show the effect of the current situations that represented by the construction of obstructions ( dyke with pipes)a cross MOD and the lateral canal named as Al-Khamisiyah Canal after 2009 on the pumping station, this effect is appearing through the water levels at D/S of the pumping system, the performance of pumps and consumed power by pumps. Two groups of scenarios were used. The first group is simulated with the unsteady state for the longitudinal water levels and contained 2 scenarios . The second group simulated in the unsteady state for the performance of the pumps included 4 scenarios as presented in **Table 6**.

**Table 6.** Suggested scenarios.

	Scenario name	Details	
First Group	OC	operation of Main Outfall Drain with current conditions	
	OI	operation of Main Outfall Drain with improved conditions	
Second Group	DH	operation of pumping system with designed head	
		with current situations DH1	without current situations DH2
	CH	operation of pumping system with non-designed head	
		with current situations CH1	without current situation CH2 as in the design

The operation of all scenarios was limited by the existing of the dyke across the MOD and the lateral canal,so, a limited number of pumps is used in the simulation (the discharge is below 80 m<sup>3</sup>/sec).The first group of suggested scenarios based on unsteady state flow condition and includes the current situation this is indicated by the symbol **OC** in **Table 6**. Where the available data and records were used.

The first group also contains the operation of MOD in the improved case **OI**, which is represented by the original design without the dyke and Khamisiyah Canal and using the same data as described earlier.

For the second group of suggested scenarios containing two main subgroups, each containing 2 scenarios ,so the system is simulated as unsteady state, for the first scenario of this group , the operation of the pumping system with design head ( the difference between upstream water level and downstream water level )of pumping station, and using design consuming power ,it is named as **DH**. In the second scenario of this group is simulated by using the current levels and using current consuming power in pumping system( according to actual operation of the



Station), this is indicated by the symbol CH.

**5. RESULTS AND DISCUSSION**

Includes two sets of results

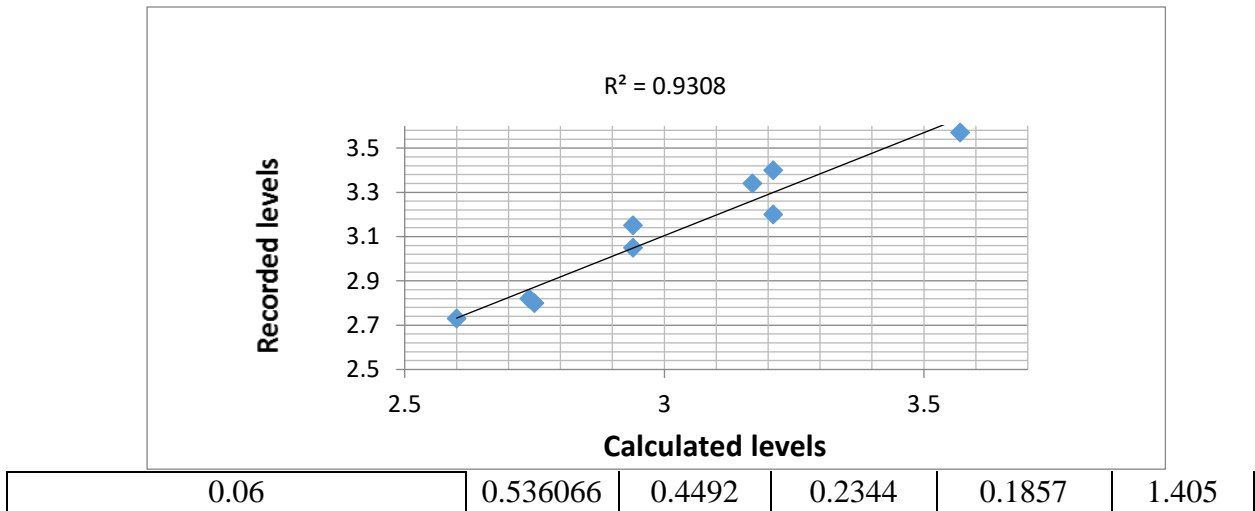
**5.1 Results of calibration and verification processes**

The calibration process was done by using the equation of the square root calculation of the intermediate error which is considered a common equation where it analyzes the deviation at a high accuracy between the estimated values (calculated or measured) which gave the minimum sum of square root equations for all Manning Coefficient values is equal to 0.7366 at n=0.044(a according to available information) as shown in **Table 7** and verification process which gave a good correlation coefficient of R2 = 0.9308 as shown in **Fig. 4**, these two processes were completed by using available recorded data from the years 2015 to 2018

**Table 7** Summary of the calibration process .

Discharge M.O.D (m3/sec)	56.7	46.8	35.6	20.4	ΣRMSE
Discharge ALKhamisiyah	37.13	29.4	20.4	13.1	
Date	5/1/2015	8/3/2015	16/5/2018	13/9/2017	
(n) Manning	R.M.S.E	R.M.S.E	R.M.S.E	R.M.S.E	
0.03	0.381925	0.2933	0.3672	0.4921	1.5346
0.032	0.331612	0.2502	0.3376	0.4739	1.3933
0.035	0.258005	0.1866	0.2934	0.4407	1.1787
0.036	0.22701	0.1686	0.2799	0.4343	1.1098
0.037	0.208886	0.1515	0.2632	0.4226	1.0462
0.039	0.164621	0.1145	0.2346	0.4032	0.9169
0.04	0.147196	0.0938	0.2202	0.3915	0.8526
0.041	0.137961	0.0852	0.2074	0.3851	0.8157
0.042	0.130384	0.0794	0.1936	0.3735	0.7769
0.043	0.126754	0.0819	0.1808	0.3638	0.7532
0.044	0.125565	0.0866	0.1745	0.3500	0.7366
0.045	0.13784	0.0998	0.1633	0.3424	0.7434
0.046	0.151107	0.1169	0.1533	0.3327	0.7540
0.047	0.169017	0.1364	0.1447	0.3189	0.7690
0.048	0.193563	0.1572	0.1431	0.3114	0.8052
0.049	0.217639	0.1831	0.1377	0.3017	0.8401
0.05	0.241454	0.2049	0.1370	0.2879	0.8712
0.052	0.298049	0.2533	0.1443	0.2706	0.966
0.054	0.353553	0.2970	0.1529	0.2299	1.033
0.056	0.411299	0.3455	0.1776	0.2299	1.164
0.058	0.47304	0.3999	0.2031	0.2051	1.281





**Figure 4** The relationship between calculated and recorded levels (verification process)

### 5.2 Results of scenarios



For the first group of scenarios, the longitudinal scheme of the MOD extends from the D/S of the pumping system from Head Basin, and then Syphon to the location of a dyke with pipes and it extends to the distance after the dyke. The longitudinal section represents the case of levels when operated according to the current operation and improved operation. The simulation was carried out by using three types of discharges: 25, 45, 75 m<sup>3</sup>/sec, which represent the stable discharges through the simulation process for operating a single pump, two pumps and four pumps respectively during a period of time, which make the model is stable. The data were selected from the recorded daily data, which include the consumed power, the number of pumps and the levels of Basin in U/S and D/S of pumping station. The simulation results as shown in Fig.5, Fig.6 .

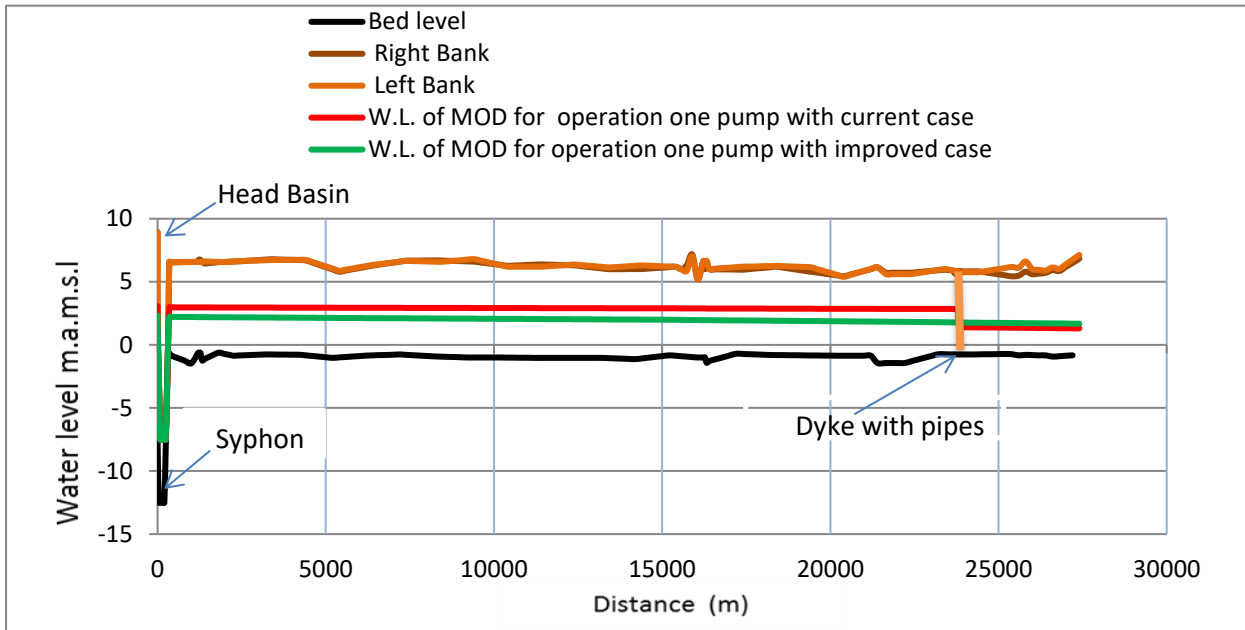
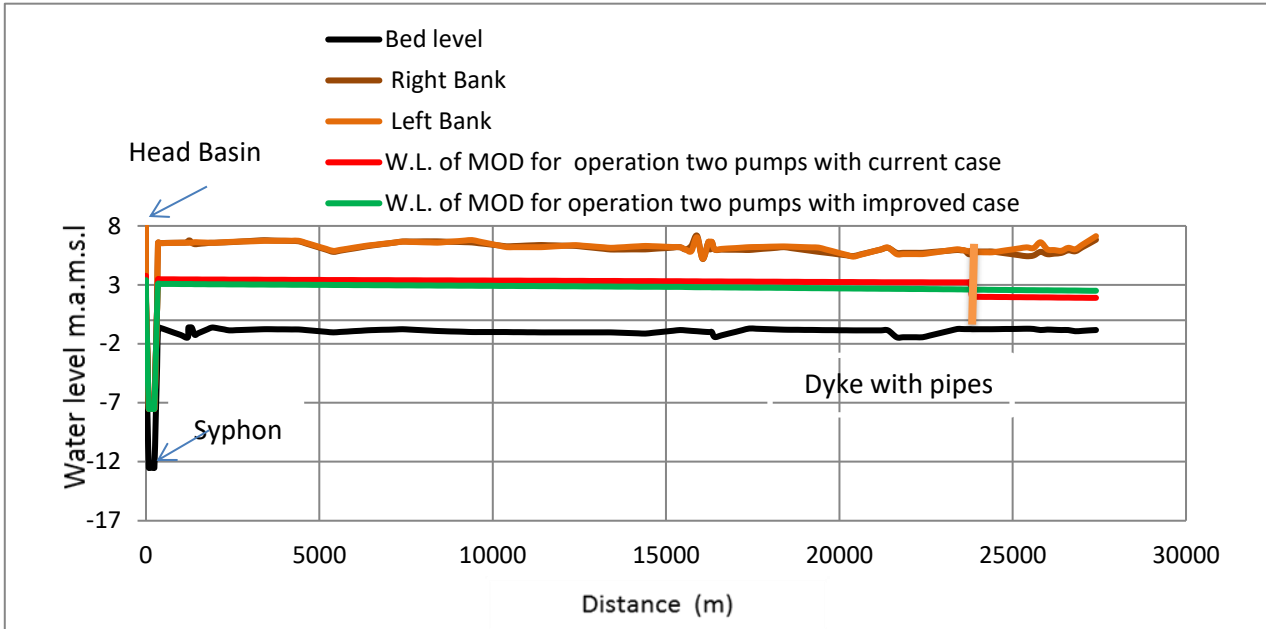


Figure 5 Profile of water levels of MOD in current conditions OC and improved conditions OI with single pump.

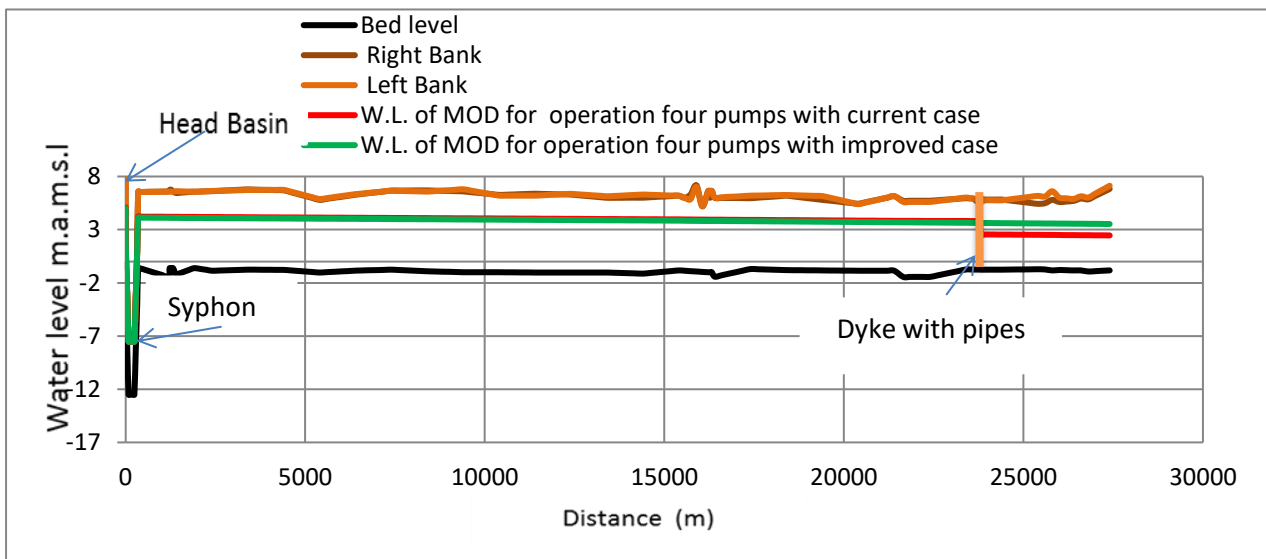


**Fig.5** the simulation result in the case of operation a single pump showed the dyke with pipes and Khamisiya Canal caused in increasing of the levels of water from 0.75 to 1m where the levels of water in OC scenarios(operation of Main Outfall Drain with current conditions) which is indicated by red line compared by the levels of water in OI scenarios ( operation of Main Outfall Drain with improved conditions) which is indicated by green color.



**Figure 6.** Profile of water levels of MOD current conditions **OC** and improved conditions **OI** with two pumps

**Fig.6** the simulation result in the case of operation two pumps showed the dyke with pipes and Khamisiya Canal caused by increasing in the levels of water from from 0.37 to 0.6 where the levels of water in OC scenarios(operation of Main Outfall Drain with current conditions) which is indicated by red line compared by the levels of water in OI scenarios( operation of Main Outfall Drain with improved conditions) which is indicated by green color .



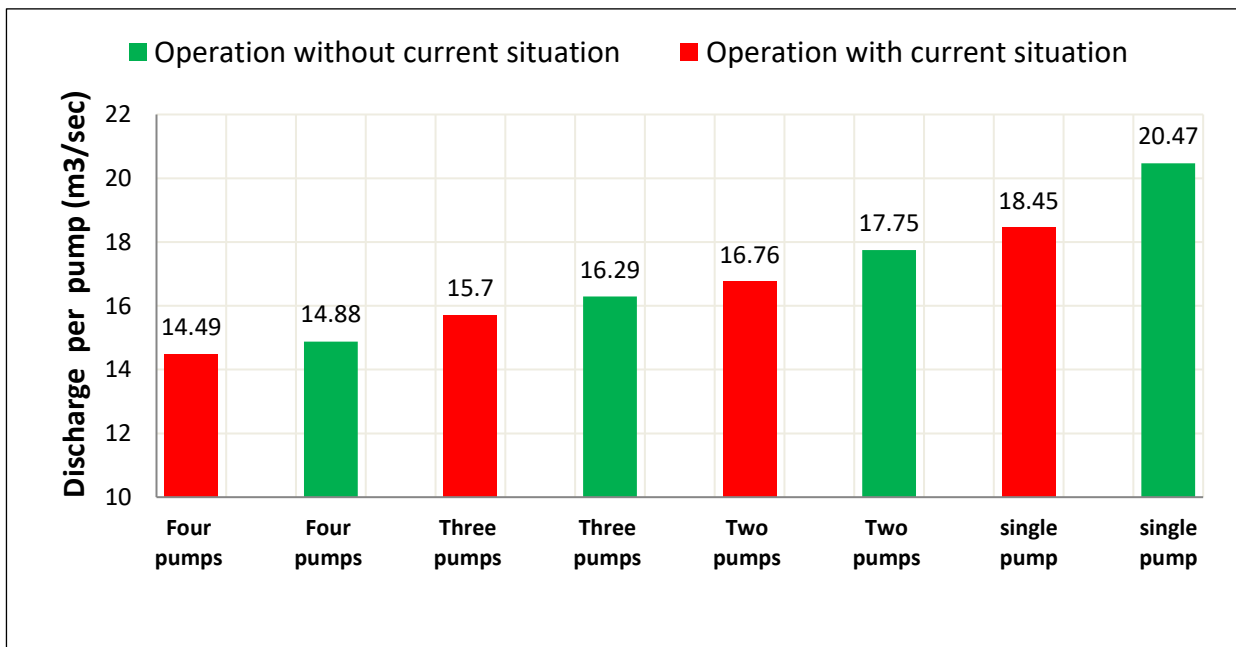
**Figure 7.** Profile of water levels of MOD in current conditions **OC** and improved conditions **OI** with four pumps.



**Fig.7** the simulation result in the case of operation four pumps showed the dyke with pipes and Khamisiya Canal caused by increasing in the levels of water from 0.09 to 0.18 m where the levels of water in OC scenarios (operation of Main Outfall Drain with current conditions) which is indicated by red line compared by the levels of water in OI scenarios ( operation of Main Outfall Drain with improved conditions) which is indicated by green color.

The simulation also showed that the head difference between the upstream and downstream of dyke in OC scenarios was 1.25 m when operation four pumps and 1.45 m in single pump, i.e., the head loss between the upstream and downstream of the dyke is significant in the low discharges . From all of the above, The effect of the current situation on the designed section of the MOD of the levels is increasing in low discharges.

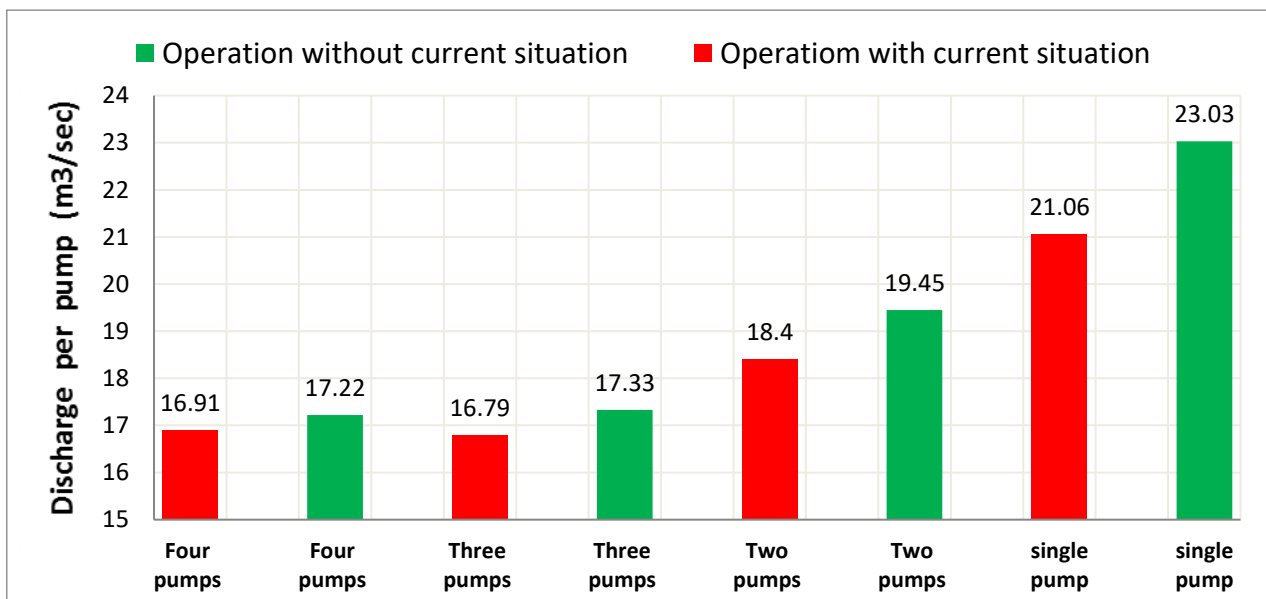
For the second group of suggested scenarios, there are several limitations in the operation of the pumping system in DH scenarios as mentioned above which limited the operation of more pumps in simulation processes. Therefore, the assumptions which used in DH scenarios include using the least designed head of 4.25m as an initial designed head of the pump, and the designed consumed power for the pumps which equal to 1184 kw, where the simulations are running by using a number of pumps starting from single pump to four pumps. The simulation results of DH scenarios showed that the presence of the current situations DH1 on the MOD effects on the performance of pumps as shown in Fig. 8, where the highest value of reduction of the performance of single pump whether situations exists (the dyke with pipes and Khamisiya Canal) or not during the time of operation is equal to 9.87% when running a single pump, 5.58% in two pumps, 3.62% in three pumps and 2.62% in four pumps, the effect of a dyke with pipes and Al-Khamisiyah Canal is significant when the pumps are operated in low discharges and less when operation of more pumps. The simulation process also showed that the consumed power by the pumps is increasing in the current situations when running single pump, where the average of increasing in consumed power is 3 kw/hour.



**Figure 8 .** The performance of single pump when operation with designed head DH scenario.



For **CH** scenario, as shown in **Table 6**, which includes operation of pumping system with non-designed head, which include making the initial head of pump between the U/S and D/S of the pumping system less than 1.5 m and the consumption power of the pump equal to 800 kW according to the daily operation of the pumps, The value of consumed power was chosen randomly from daily operation to represent the average of consumed power. The simulations were conducted by using the above information and gave the following results as shown in **Fig. 9**, were the highest value of reduction of single pump performance, whether current situations exist **CH1** or not **CH2** during the time of operation equal to 8.55 % when running single pump 5.4 % in two pumps, 3.11 % in three pumps and 1.8% in four pumps, the effect of a dyke with pipes and Al-Khamisiyah Canal are significant when low discharges and less when increasing the discharge. The simulation process also showed that the consumed power by the pumps is increasing in the current situations when is running single pump or two pumps, where the average of increasing in consumed power is 68 kw/hour and 30 kw/hour in operation one and two pumps respectively.



**Figure 9.** The performance of single pump when operation with non-designed head (current water levels) in **CH** scenario.

### CONCLUSIONS

1. The hydraulic effect of the current situations which is represented by the construction of dyke with pipes and Al-Khamisiyah Canal on the water levels at D/S of the pumping system is increasing the levels from 0.37 to 0.6m in the case of two operated pumps and 0.75 to 1 m in case single operated pump.
2. The effect of the current situation is significant with the operation of single pump and decreases with the increasing number of operating pumps .The largest value of decrease in the performance of pumps is noticed as follows: 9.87% in single pump, 5.58% in two pumps, 3.62% in three pumps and 2.65% in four pumps while the effect of the current situations in the non-designed water levels as follows: 8.55% in single pump, 5.41% in two pumps, 3.11% in three pumps and 1.8 % in four pumps.



3. The effect of the current situations increases the consumed power by the pumps, especially in the low discharge (less than  $40 \text{ m}^3/\text{s}$ ).
4. The current situation restricted the pumping station from operating with its full discharge capacity.

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## NOMENCLATURE

D/S = downstream

MOD= Main outfall drain

Q = discharge,  $\text{m}^3/\text{sec}$

U/S= upstream