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Simulation of Pressurized Irrigation System in South of Iraq Using EPANET Model

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Abstract

Water scarcity in Iraq is a real challenge that could be attributed to the lack of water inflows from the riparian countries and the impact of the climate change worldwide and in order to find alternatives with the appropriate solutions, the Ministry of Water Resources in Iraq intends to use modern irrigation systems in order to reduce the losses of water by increase transportation efficiency through using close and motorize irrigation system. Furthermore, educate farmers to adopt modern irrigation methods in field to reduce the runoff, evaporation and deep percolation losses. This research aimed to investigate two simulations of EPANET software program to compare the overall effect of sectoring in pressure, velocity, and pump station with indirect effect on pipe diameter and the total cost of the project. The results come with many facts with the focus on the effect in pressure intakes and velocity in pipeline with operation time and the default age of pipe station. Results of S1 illustrated the pressure in all intakes is less than the design standard of the system (2.5 bar) where the maximum pressure in system in Junction (5) is (0.721 bar) which precludes the sprinkler system to operate with high efficiency and prevents the distribution of water inside the sprinkler holes as a result of low pressure. Whilst the simulation of (S2) inferred by comparison that it is better in terms of the operating pressure of intakes, velocity in pipeline and default age of pump station. The minimum pressure in system in junction (28) is (2.632 bar) which it reaches the design standard even though using the same pump station in simulation S1. The velocity is acceptable in all pipeline system and the operation time is 18hr per day less than in simulation S1 which gives a rest period to the pump.

Key words: EPANET, Irrigation, Simulation, Velocity, Pipeline, default age

محاكاة لمنظومة الري المغلق في جنوب العراق باستخدام برنامج النمذجة EPANET

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الخلاصة

ان شحة المياه في العراق تعتير من التحديات الحقيقة ويعزى السبب في ذلك الى نقص تدفق المياه من الدول المشاطئة للعراق والتاثيرات التغير المناخي في جميع انحاء العالم ولغرض ايجاد الحلول البديلة والملائمة, اعتمدت وزارة الموارد المائية في العراق على استخدام انظمة الري الحديثة لغرض تقليل الضائعات المائية من خلال زيادة كفائة النقل باستخدام انظمة الري المغلقة والممكننة. بالاضافة الى تثقيف الفلاحين على تبني استخدام طرق الري الحديثة في الحقل لغرض تقليل ضائعات الجريان السطحي, التبخر, وضائعات التغلغل العميق. يهدف البحث الى دراسة اثنان من المحاكاة المنذجة باستخدام برنامج EPANET ومقارنة كل التاثيرات من تقسيم وتوزيع الضغوط, السرعة, محطة الضخ, مع التاثير الغير مباشر من تغيير اقطار الانابيب والكلفة الاجمالية للمشروع. اوضحة النتائج الكثير من الحقائق مع التركيز على تاثير الضغط في الماخذ الحقلية والسرع في خط الانبوب الناقل مع الوقت التشغيلية والعمر الافتراضي لمحطة الضخ. نتائج المحاكاة الاولى (S1) توضح ان الضغوط في داخل المنظومة بالكامل اقل من المعيار التصميمي المطلوب لعمل المنظومة (2,5 بار) حيث ان اعلى ضغط في المنظومة هو عند منفذ رقم (5) بضغط يصل الى (0,721 بار) وبالتالي يقلل من عمل المنظومة بكفائة عالية ويمنع توزيع المياه داخل فتحات المرشات والذي هو كنتيجة للضغط المنخفض. بينما نتائج المحاكات الثانية (S2) تدل بالمقارنة انها افضل في تشغيل الضغوط عند الماخذ الحقلية, السرع في الخط الانبوب الناقل و العمر الافتراضي لمحطة الضخ. حيث ان اقل ضغط في المنظومة هو عند منفذ رقم (28) بقيمة (2,632 بار) والذي يحقق المعيار التصميمي المطلوب على الرغم من استخدام نفس محطة الضخ المسخدمة في المحاكات الاولى (S1). السرعة مقبولة داخل الانبوب الناقل لكل المنظومة والوقت التشغيلي هو 18 ساعة في اليوم وهو اقل من ما هو معتمد في المحاكات الاولى (S1) مما يعطي وقت راحة للمحطة خلال اليوم.

الكلمات الدالة:- برنامج النمذجة EPANET, الري , محاكات, السرعة, خط الانبوب الناقل, العمر الافتراضي

1. Introduction

Iraq is one of the most countries affected by climate change and it is expected that there will be a high scarcity of irrigation water in the near future. Thus, it is essential to adopt the best design and research methods for attempting to reduce water losses and evaporation. Pressurized irrigation methods include both sprinkler and drip irrigation methods where water is applied through network of pipelines by means of pressure devices. The water required by the crop is applied in the form of spray by using some devices, wherein the water application rate should be somewhat lesser than the soil infiltration rate to avoid run off or stagnation of water in the field (Vikram, 2020). This irrigation system is a hydraulic infrastructure that conveys water from the source like river of channel to the field; it consists of elements such as pipes, pumps, valves, tanks and reservoirs. The most important consideration in designing and operating system is to satisfy agricultural crops demands under a range of quantity and quality considerations.

EPANET is public domain software developed by the Water Supply and Water Resources Division of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory (Rossman, 2000)

Pipe network analysis initially started early in 1940. Years later, two network analysis programs were introduced by Shamir and Howard (1968) and Epp and Fowler (1970).Both programs used the Newton-Raphson method to linearize the nonlinear mass and energy equations. The EPANET model used for water distribution network analysis is composed of two parts: (1) the input data file and (2) the EPANET computer program. The data file defines the characteristics of the pipes, the nodes (ends of the pipe), and the control components (such as pumps and valves) in the pipe network. The computer program solves the nonlinear energy equations and linear mass equations for pressure sat nodes and flow rates in pipes.

Iraq water management plans should be efficient for the worst conditions that will be a vital issue facing water resources sector. For that, the researches should focus on the drought hazard and using modern irrigation methods. The current research aimed to check the performance of water distribution network of Al- Muammer area of Basra city using hydraulic simulation software EPANET model. This kind of research is very important especially in Iraq due to the climate change consequences and the water policies of the neighboring countries. The water strategies plan should take the results of such research as a start for sustainable long plans of using modern irrigation.

2. Methodology

This research report all improvements required in two distribution systems network and the model of operation, in order to improve the quantity and quality of water distribution to the field and provide minimum required pressure not less than 25m in all intakes at field (required operating pressure for sprinkler irrigation system).

The EPANET software program provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. The hydraulic simulation performed by EPANET field information such as flow and head losses in links(pumps ,pipes and valves),demands at junctions (Intakes), heads, pressures, levels and volumes for water storage. The main data required to operate the model is the ground level of study area, irrigated area for each junction in order to calculate the discharge of each intake based on the water duty and the base information of pump station. The expected outputs of the program will depend mainly on the velocity in pipes and the pressures at intakes.

2.1. Study area

In this research, the study area is within the Southern Part of Iraq called Al- Muammar which it is a district belonging to the city of Al-Faw (Basra Governorate). The study area is about 1518 Don (380 Ha) and it’s irrigated from Kitaban channel with U-Shape Section. The design discharge of area depending on water duty of region is 575 Liter/sec. The field lies at 48^{o}41’ east longitude and 30^{o}09’ north altitude as depicted in Figure (1).

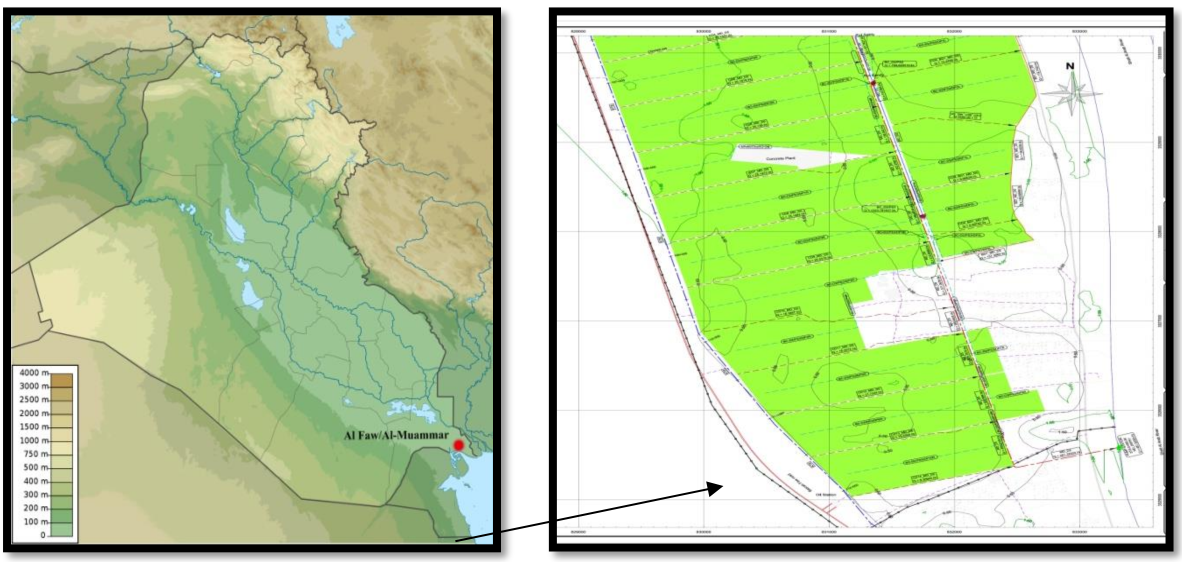


Figure (1): Study area

2.2. Hydraulic Modelling Capabilities

EPANET contains hydraulic analysis engine that includes the following capabilities: -

1. Places no limit on the size of the network that can be analyzed.
2. Computes friction head loss.
3. Variable speed pumps and computes pumping energy and cost.
4. Perform modelling for various types of control valves like (check valve, pressure regulating, and flow control valves).
5. Considers multiple demand categories at nodes.
6. Models pressure dependent flow from sprinklers.

Each network element has a hydraulic equation. For pipe equations, the Hazen-Williams formula is used (Brdys and Ulanicki, 1994). In the optimal scheduling problem it is required that all calculated variables satisfy the hydraulic model equations. The network equations are usually non-linear and are embedded as inequality and equality constraints in the optimization problem.

The hydraulic head loss by water flowing in a pipe due to friction with the pipe walls can be computed using one of three different formulas:

1. Hazen-Williams formula
2. Darcy-Weisbach formula
3. Chezy-Manning formula

The Hazen-Williams formula is the most commonly used head-loss formula in the US. It cannot be used for liquids other than water and was originally developed for turbulent flow only. The Darcy-Weisbach formula is the most theoretically correct. It applies over all flow regimes and to all liquids. The Chezy-Manning formula is more commonly used for open channel flow. Each formula uses the following equation to compute head-loss between the start and end node of the pipe:

hL = AqB

Where, hL= head-loss (Length), q = flow rate (Volume/Time), A = resistance coefficient, and B = flow exponent. Table (1) lists expressions for the resistance coefficient and values for the flow exponent for each of the formulas. Each formula uses a different pipe roughness coefficient that must be determined empirically.

Table (1): Pipe Head-loss formula for full flow

Formula	Resistance coefficient (a)	Flow Exponent (b)
Hazen-Williams	4.727c-1.852d-4.781L	1.852
Darcy-Weisbach	0.0252f(ε,d,q)d-5L	2.000
Chezy-Manning	4.66n2d-5.33L	2.000

es:

Hazen-Williams roughness coefficient

Darcy-Weisbach roughness coefficient (ft)

riction factor (dependent on ε, d, and q)

Manning roughness coefficient

pipe diameter (ft)

pipe length (ft)

flow rate (cfs)

Table (2): Roughness Coefficient for new pipe

Material	Hazen-Williams (C)	Darcy-Weisbach	Chezy-Manning
Cast Iron	130-140	0.85	0.012-0.015
Concrete or Lined Concrete	120-140	1.0	0.012-0.017
Galvanized Iron	120	0.5	0.015-0.017
Plastic	140-150	0.005	0.011-0.015
Steel	140-150	0.15	0.015-0.017
Vitrified Clay	110	-------	0.013-0.015

2.3. Working Mechanism

The first step is to draw and design the targeted irrigation network within the study area with the definition of water duty and demand in every Farm-Turnout (F.T.O) depending on the area of farm in (Hectare). The water duty of area is (0.862 L/S/Ha) for 24hr depending on the outputs of Strategic Study of Ministry of Water Resources in Iraq. Figure (2) shown the distribution network for 380 Ha (1518 Don) and location of pump station (PS4).The number of intakes (F.T.O) is (30) and the pump station working with discharge (575 l/s) and head equals to 35m.

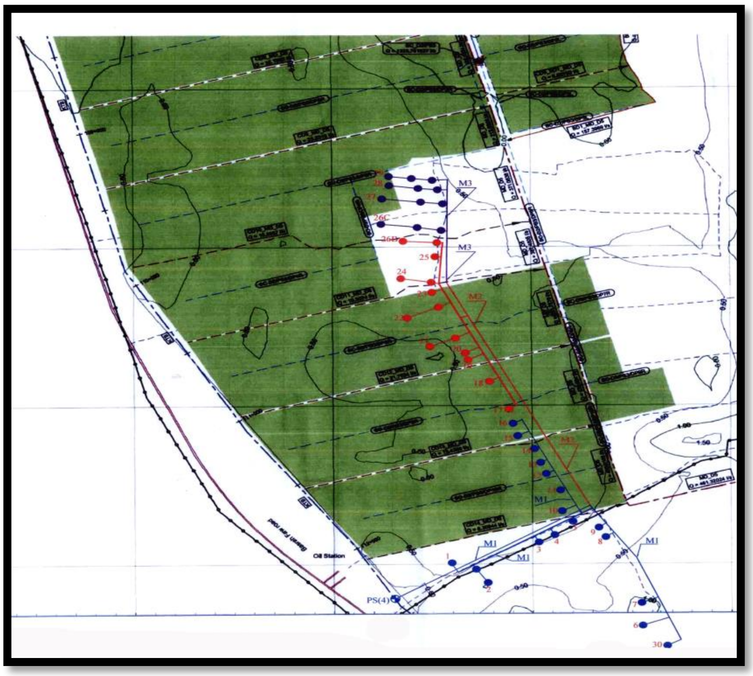


Figure (2): Irrigation Network Distribution

The properties of the objects that make up the system need to be amended which includes the editing of the properties and inserting the required data in various objects like reservoir (The Kitaban channel was adopted as the system's water source), pipes, junctions, etc.

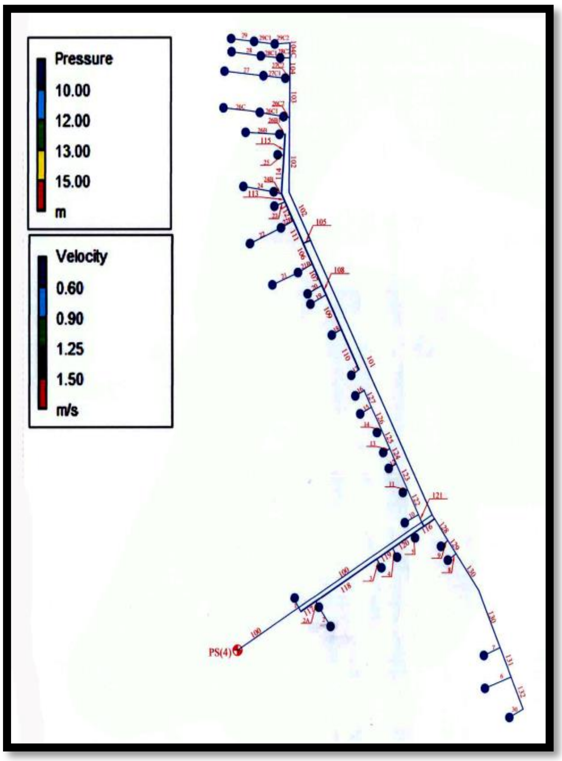


Figure (3): System Pipelines Number

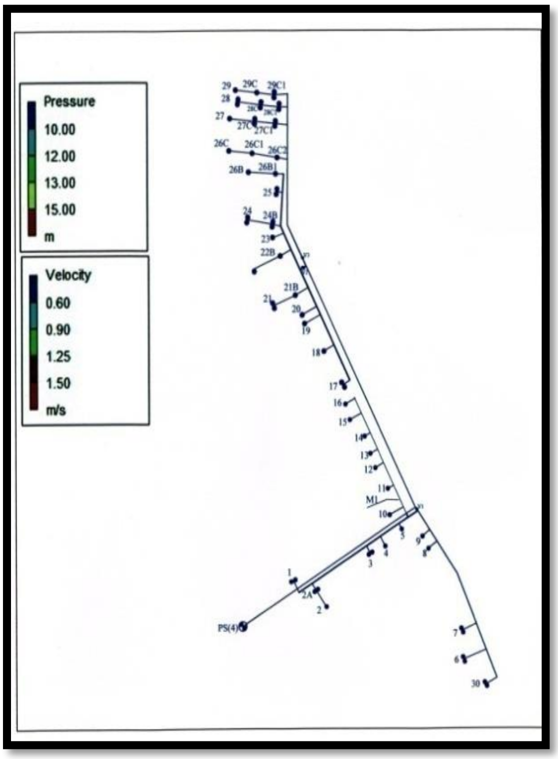


Figure (4): System Intakes Number

Table (3) presents the basic of information data of pipeline system using EPANET model includes: Name of pipe (pipe number), Length, Diameter and roughness of pipes. The type of pipes is plastic (U.P.V.C) pipes.

Table (3): Design Information Data for pipeline system

Pipe No.	Length Of Pipe (m)	Pipe Dia. (mm)	Roughness (C)
1	100	250	150
2	150	200	150
2A	30	250	150
3	40	225	150
4	40	125	150
5	35	125	150
6	100	225	150
7	50	200	150
8	20	160	150
9	10	125	150
10	50	125	150
11	20	160	150
12	30	160	150
13	40	160	150
14	50	160	150
15	60	160	150
16	60	160	150
30	70	250	150
17	30	250	150
18	20	125	150
19	50	125	150
20	50	160	150
21	150	250	150
21B	50	250	150
22	150	250	150
22B	50	250	150
23	40	160	150
24	150	250	150
24B	50	315	150
25	20	200	150
26B	150	160	150
26B1	50	200	150
26C	100	160	150
26C1	100	250	150
26C2	50	250	150
27	100	160	150
27C1	150	250	150
27C2	50	315	150
28	150	200	150
28C1	150	250	150

Pipe No.	Length Of Pipe (m)	Pipe Dia. (mm)	Roughness (C)
28C2	50	315	150
29	100	160	150
29C1	150	250	150
29C2	50	315	150
100	1100	630	150
101	1560	630	150
102	220	630	150
103	220	630	150
104	90	500	150
104C	60	315	150
105	50	630	150
106	110	400	150
107	110	315	150
108	40	315	150
109	170	315	150
110	190	315	150
111	100	500	150
112	100	400	150
113	40	400	150
114	170	250	150
115	90	200	150
116	65	630	150
117	90	250	150
118	270	315	150
119	90	400	150
120	110	400	150
121	120	400	150
122	130	400	150
123	115	400	150
124	105	315	150
125	80	315	150
126	90	250	150
127	110	160	150
128	150	400	150
129	70	400	150
130	195	315	150
131	280	315	150
132	160	250	150

Table (4) shown the information data for all intakes in system include the net area in (Don) and the required discharge depending on the type of crop for each intake

Table (4): Design Information Data for Intakes

Intakes No.	Net Area (Don.)	Demand (L/S)
1	48	51.50
2	72	72.1
2A		
3	48	51.50
4	10	10.40
5	10	10.40
6	44	41.20
7	56	51.50
8	24	30.90
9	8	10.40
10	10	10.40
11	20	20.60
12	32	30.90
13	24	30.60
14	28	30.90
15	28	30.90
16	36	30.90
17	64	61.80
18	12	10.40
19	12	10.40

Intakes No.	Net Area (Don.)	Demand (L/S)
20	20	20.60
21	76	82.40
21B		
22	80	82.40
22B		
23	20	20.60
24	108	113.30
24B		
25	40	41.20
26B	136	133.90
26B1		
26C		
26C1		
26C2		
27	152	154.50
27C		
27C1		
28	132	134.00
28C		
28C1		
29	112	113.30
29C		
29C1		
30	56	61.8

3. Discussions

In order to check the operation system which includes pressure in farthest intake in critical path of the system, average velocity in pipeline, quantity and quality of water distribution, the first simulation (S1) will consider the operation of all intakes system at the same time (1518 Don.) for 24hr (water duty 0.862 l/s/Ha per day). The operation pressure at the pump station (35m) and the discharge (575 l/s). Table (5) and Figure (5) presents the output of EPANET Model for critical path of the system that includes: - pressure in intakes, velocity and friction factor in pipeline system.

Table (5): Output of EPANET Model for S1

Intake Or Pipe Number	Pressure (m)		Velocity (m/s)		Friction Factor
	Max.	Min.	Max.	Min.	
Jn 5	**7.21**	----------	----------	----------	----------
Jn 9	**7.07**	----------	----------	----------	----------

Jn 30	**5.05**	----------	----------	----------	----------
Jn 26B	----------	**2.11**	----------	----------	----------
Jn 27	----------	**2.15**	----------	----------	----------
Jn 28	----------	**2.11**	----------	----------	----------
Pi 100	----------	----------	**2.97**	----------	0.011
Pi 131	----------	----------		----------	0.015
Pi 18	----------	----------	----------	**0.45**	0.020
Pi 110	----------	----------	----------	**0.41**	0.017

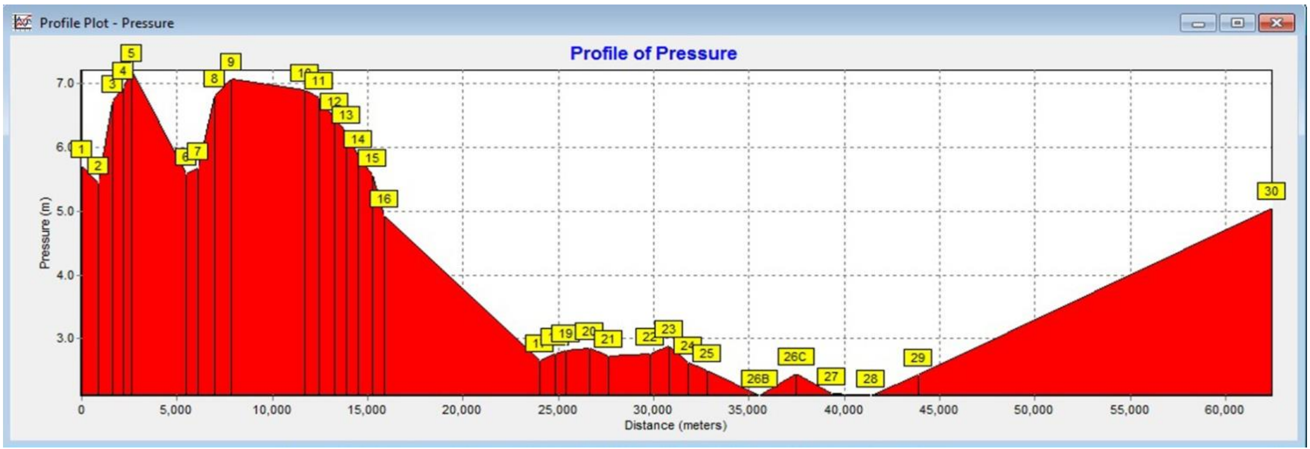
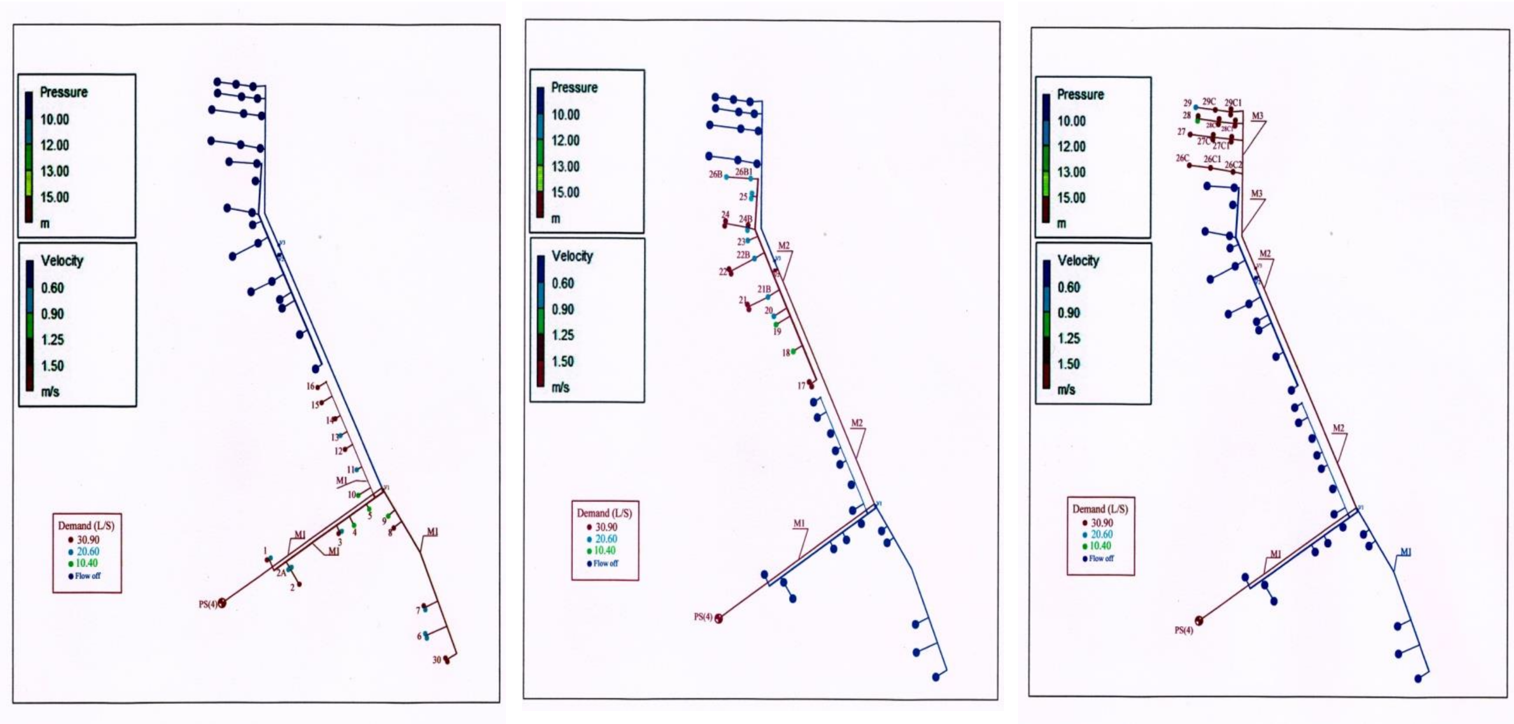


Figure (5): Pressure Profile of S1

The second simulation (S2) will consider the operation of the system with three sectors (A, B and C) every sector working for 6 hours per day as illustrated in Table (6) that presents the details of each sector and will using tree stop valves in specific sites in system in order to control the flow direction for each sector . The water duty is (4.15 l/s/Ha) for 6 hr per day and using the same pump station to compare the result with simulation (S1). Figure (6) depicts the division of intakes in each sector (A, B and C).

Table (6): Details Information for each sector in Simulation (S2)

S NO.	Group No.	Net Area (Don)	Water Duty (L/S/Ha)	Hours of Supply (Hr/Day)	Period Supply (Days)	NO. of Intakes
1	A	554	4.15	6	1.0	17
2	B	502	4.15	6	1.0	10
3	C	462	4.15	6	1.0	4



Sector A Sector B Sector C

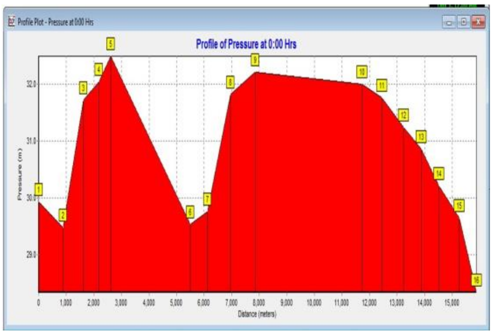
Figure (6): the Division of Intakes in Each Scoter

Table (7) and Figure (7) presents the output of EPANET Model for critical path of system for simulation (S2).

Table (7): Output EPANET Model for S2

Intake Or Pipe Number	Pressure (m)		Velocity (m/s)		Friction Factor
	Max.	Min.	Max.	Min.	
Jn 5	**32.50**	----------	----------	----------	----------
Jn 9	**32.21**	----------	----------	----------	----------
Jn 30	**28.52**	----------	----------	----------	----------
Jn 26B	----------	**27.49**	----------	----------	----------
Jn 27	----------	**26.54**	----------	----------	----------
Jn 28	----------	**26.32**	----------	----------	----------
Pi 100	----------	----------	**1.75**	----------	0.012
Pi 131	----------	----------	**1.31**	----------	0.015
Pi 18	----------	----------	----------	**0.85**	0.018

Pi 110	----------	---------	---------	**0.80**	0.016



Sector A

Sector B

Sector C

Figure (7): Pressure Profile of S1

4. Results

In this research, two simulations of pressurized irrigation systems have been presented for stay area in Basra Governorate (Southern Iraq) using EPANET Software.

The results come with many facts in the region, the effect in pressure intakes and velocity in pipeline with operation time and the default age of pipe station. The EPANET outputs explain and compare the information for each simulation (S1 and S2) technically and economically.

The results of S1 shown the pressure in all intakes is less than the design standard of the system (25m), where the maximum pressure in system in Junction (5) is (7.21 m) and that does not allow the sprinkler system to operate with high efficiency and prevents the distribution of water inside the sprinkler holes as a result of low pressure. The operation time for pump station in S1 is 24hr per day and that will reduce the default age for the pump.

The simulation (S2) explained by comparison that it's better in terms of the operating pressure of intakes, velocity in pipeline and default age of pump station. The result shown that the minimum pressure in system in junction (28) is (26.32 m) which it reaches the design standard even though using the same pump station in simulation S1. The velocity is acceptable in all pipeline system between (2.0 – 0.6) m/s and the operation time is 18hr per day less than in simulation S1 which gives a rest period to the pump.

It is concluded that the obtained results alert to explore new methods and techniques to use the modern techniques for high water use efficiency and bioengineering for crops of less water use. Furthermore, using the modern irrigation system to mitigate the misuse of surface water resources.

It's highly recommended that other researchers proceed with other programs recommended and compare the results for a full assessment of irrigation models in Iraq for much more sustainable water management plans.

5. Conclusions

This paper summarized the simulation of using EPANET model in study area by analyzing the output data from two models to find the best methods to operate the closed pressurized irrigation system technically and economically. Using Modern irrigation became a serious issue facing the water resources sector in Iraq and affects all the linked fields. As per the results, the whole study area is subjected two simulation of EPANET software to compare the overall effect of sectoring in pressure, velocity, and pump station with indirect effect on pipe diameter and the total cost of the project.

The results show there is a serious effect of dividing the irrigation system into sectors, which increase pressure in intakes to reach the design standard with acceptable velocity in pipeline system. The increase in default age of pump station decreases the total cumulative cost of the project in future. In few cases, occurrence runoff losses from the field is due to soil saturation as a cause of reducing water period from 24 hrs to 6hrs. It's highly recommended that other researchers proceed with other programs recommended with physical model study and compare the results for a full assessment of irrigation models in Iraq for much more sustainable water management plans.

In the future plan, a physical model for one of the sectors requires its design to study the effect of changing the value of water duty and appropriate treatment methods to reduce water losses.

This research depends only on the EPANET software program to compare the results of different cases, which can to benefit from other software program to obtain more detailed information that allows access to the highest levels of system design.

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