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Compared between the Measured Seepage Losses and Estimation and Evaluated the Conveyance Efficiency for Part of the Hilla Main Canal and Three Distributary Canals (HC 4R, HC 5R and HC 6R) of Hilla-Kifil Irrigation Project

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Abstract
Hilla-Kifil irrigation project in Babylon in Iraq consists of three sections: north, middle, and south. The constructed sections currently are: north, middle, and a small part of the southern section. This study was conducted on part of the Hilla main canal between two Kilometers (13.037 km) and (16.492 km) and three distributary canals are (HC 4R, HC 5R and HC 6R) in addition to the watercourses that branched thereof, these canals are lined**,** the aim of this study was to measured seepage losses from lined canals and checked the water conveyance efficiency. Seepage losses for lined canals that entered in this study were measured by inflow-outflow method and compared the results with the estimated losses by two empirical equations (Moritz and Davis-Wilson), using the reaches on the canals. The average seepage losses that was measured on Hilla main canal was (57.98 $m^3/s/10^6m^2$), (39.52 $m^3/s/10^6m^2$) for the three distributary canals (HC 4R, HC 5R and HC 6R). The standard deviation of the Hilla main canal was 22.98, (27.96) for three distributary canals. The results showed that were above the standards. The water conveyance efficiency for Hilla main canal and three Distributary canals (HC 4R, HC 5R and HC 6R) was checked. The results were (95.21, 83.68%, 81.20% and 90.33%) respectively, and when were compared with the design values were less of them.
Keywords: distributary canals and watercourses, Seepage losses, conveyance efficiency, Moritz, Davis-Wilson, inflow and outflow method.

1. Introduction

The process of lining reduces the losses of the water transported in unlined canals at a rate of 40 percent. Conveyance and the water distribution systems are most important parts of an irrigation projects, irrigation systems is built for work at a maximum efficiency. It means that the transfer of water at the minimum cost and with minimum water losses (Yaragatti, 1982). The irrigated areas are large so requires transfer of irrigation water for long distances, which leads to the losses during the transfer process and the lining is treated to minimize such losses. The lining deteriorates with the passage of time where appear a lot of cracks that eventually lead to the collapse in the layers of lining, these cracks and deterioration of lining joints are exits for water so must take the necessary measures to reduce these losses (Maghrebi et al., 2011).

There are three types of conveyance losses: operational losses, evaporation losses, seepage from sides and bed of irrigation canals and distribution systems and form a large part of the usable water. The important type of these is seepage, and it calculates either directly measurements or by empirical equations. Operational losses produce due to poor management in the distribution canals and the change in the operation systems (Saeed and Khan, 2014).

In this current research, measuring the available depth of flow and discharge for chosen locations on taken reaches of Hilla main canal and three distributary canals which branch from Hilla main canal (HC 4R, HC 5R and HC 6R) during months (Dec., Jan., Feb. and Mar.), to measure the seepage losses by inflow-outflow method and estimated its amount by two empirical formulas (Moritz Formula and Davis and Wilson Formula) and compared between them, and evaluated the conveyance efficiency for these canals.

2. Materials

2.1 Study Area

This study was conducted in Hilla-Kifil irrigation project; the project area is situated between 44˚13' to 44˚26' eastern longitude and 32˚13' to 32˚43' northern latitude and which constructed in the mid-eighties of the last century. The project area covers 57,500ha or 230 donums and extends about 50 km from north to south and 20km from west to east as shown in Figure (1), (Feasibility Report of Hilla-Kifil project, July 1980). The Euphrates River is the main source that supplied water to the project. The seepage was calculated from lined canals by taking some reaches on Hilla main canal and three distributary canals are (HC 4R, HC 5R and HC 6R) as shown in Figure (2), detailing no.1 as shown in Figure (3), and detailing no.2 as shown in Figure (4).

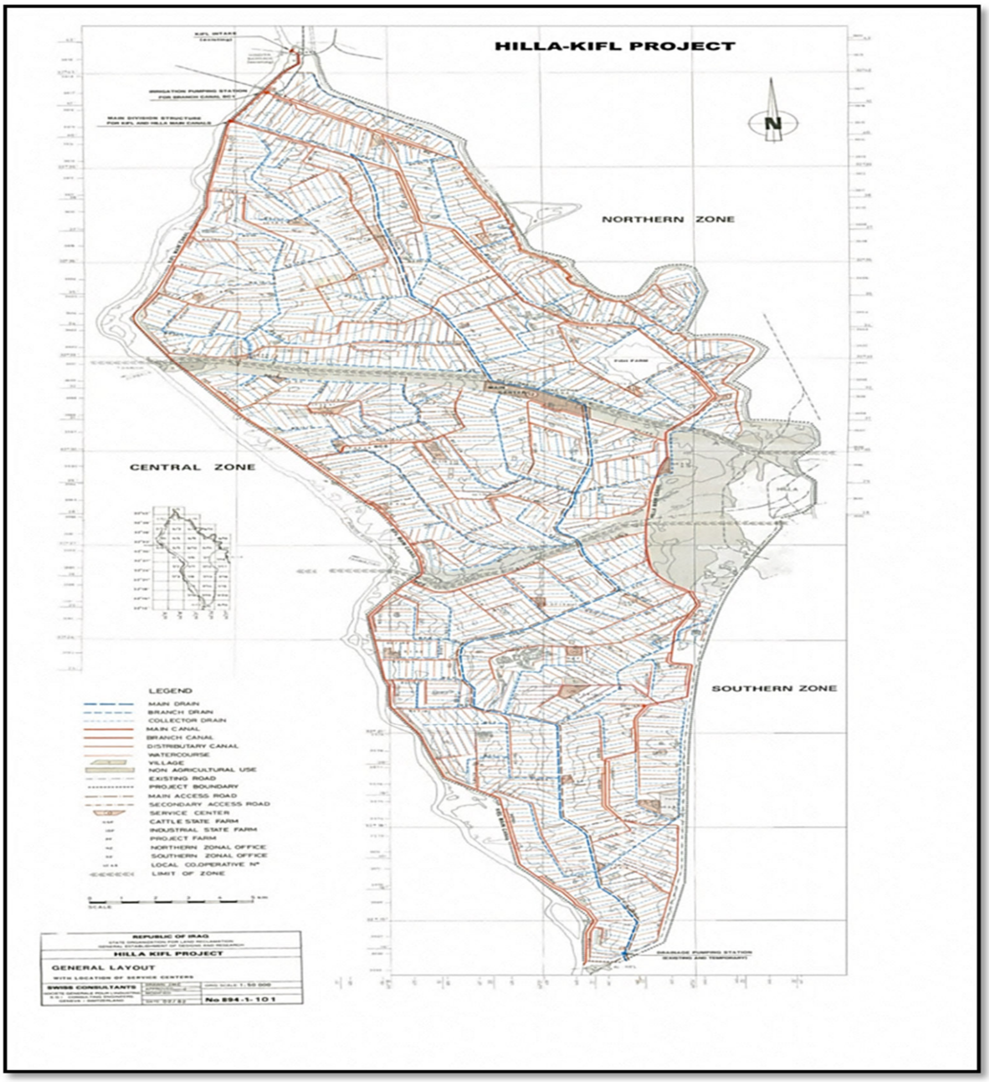

Figure (1) location map of Hilla-Kifil irrigation project (Hilla-Kifil irrigation project management in Babylon)

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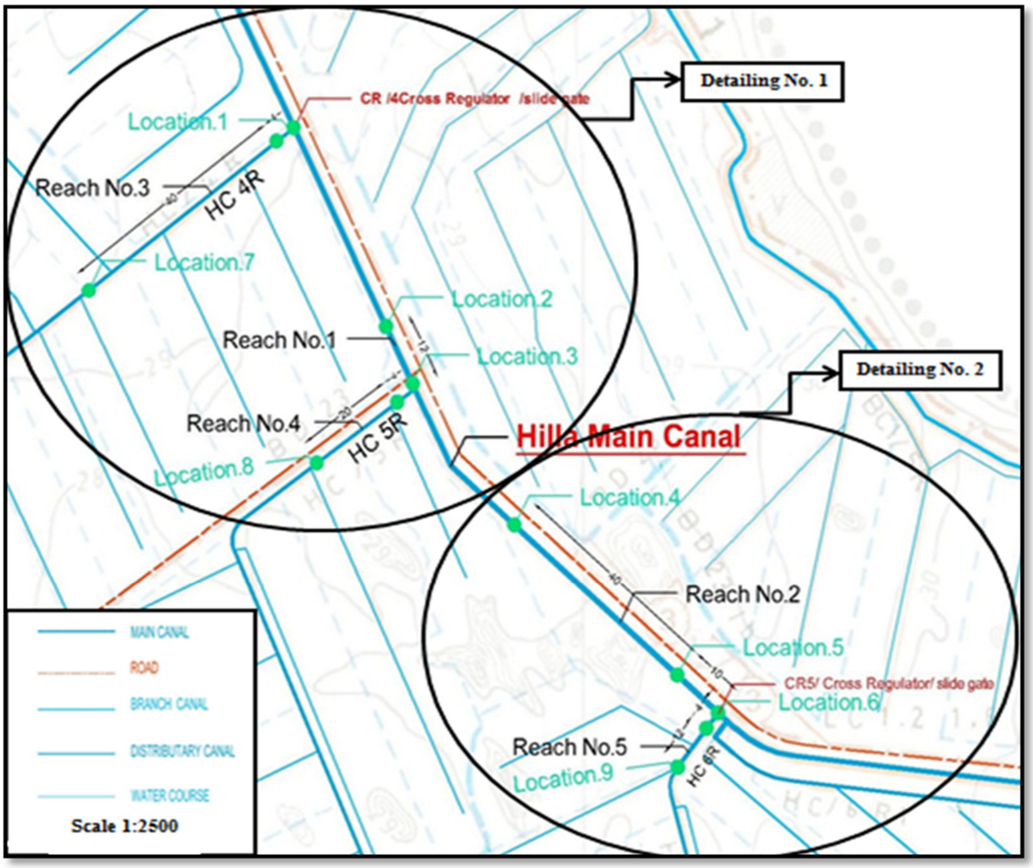

Figure (2) reaches and locations of taking sample on Hilla main canal and three distributary canals (HC 4R, HC 5R and HC 6R)

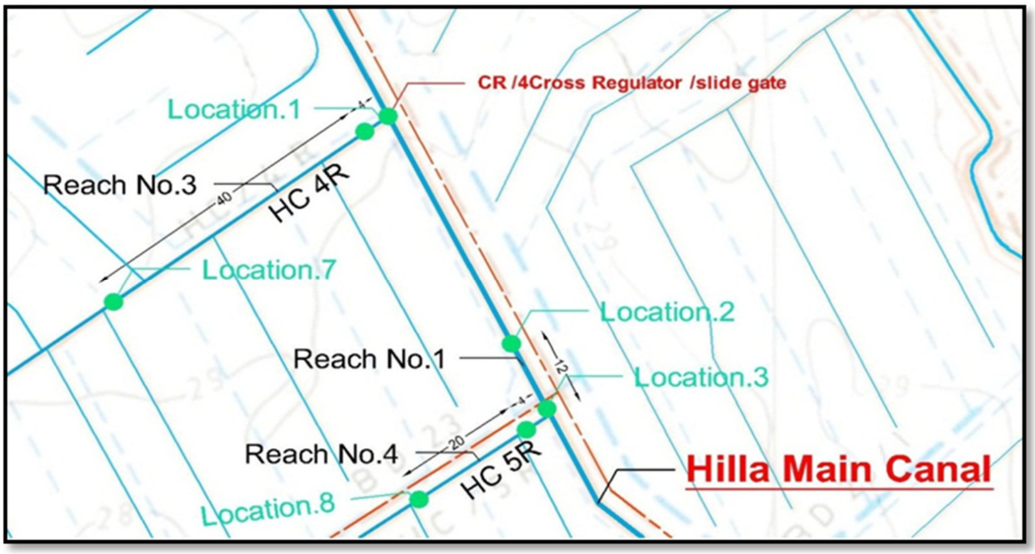

Figure (3) shows Detailing No.1 which includes locations (1, 2, 3, 7, and 8) and reaches (No.1, No.3 and No.4)

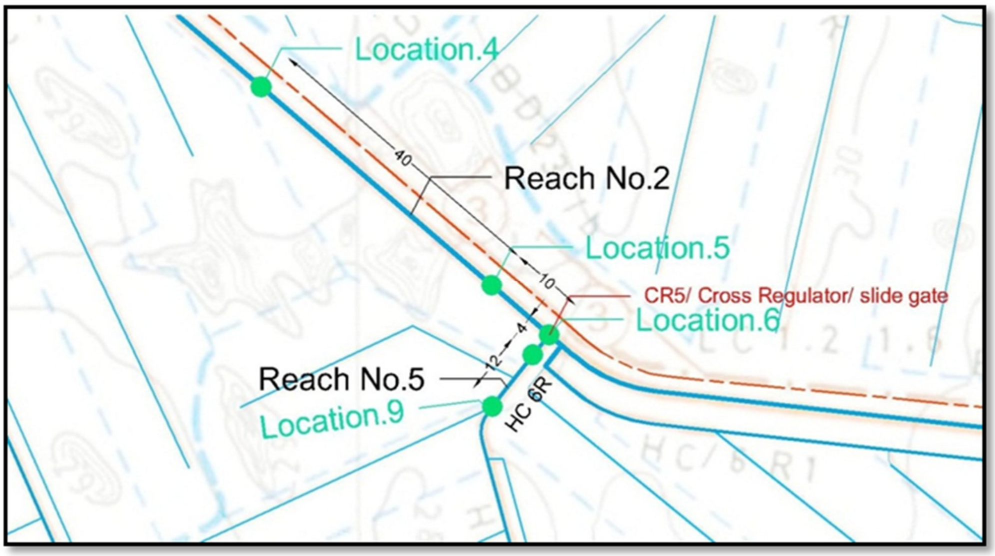

Figure (4) shows Detailing No.2 which includes locations (4, 5, 6 and 9) and reaches (No.2 and No.5)

2.2 The Measured Discharge of Hilla Main Canal and Three Distributary Canals

Hilla-Kifil irrigation project is working at a quotas system so that some measurements were conducted when water was provided to canals (full capacity) and others do not. In February, the quotas was to second sector during the measurements which included the two distributary canals within this study (HC 5R and HC 6R), either the months of December and January, the quotas was to first sector and which included (HC 4R) falling within this study and the month of March, the quotas was to another sectors. The variation of discharge of Hilla main canal that depends on the quotas table during the deferent month is shown in Figure (5).

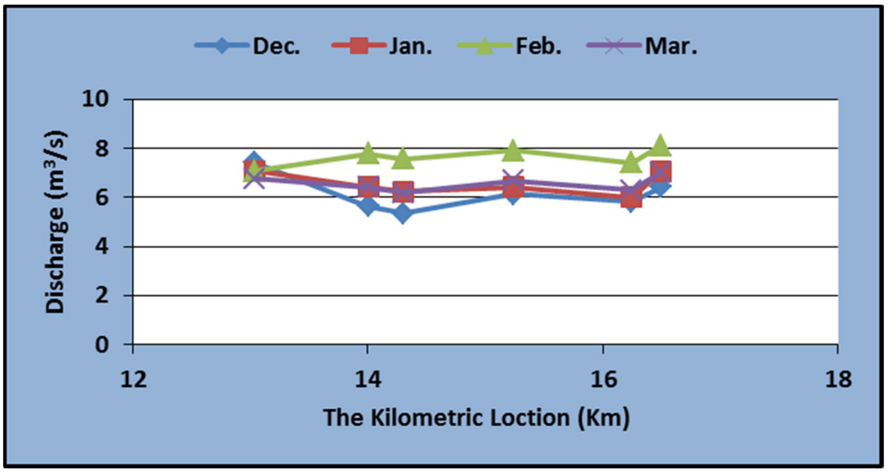

Figure (5) the variation of discharge for Hilla main canal during different months for six points

In this research, the depth was measured in the inlet and outlet of each reach at the same time approximately so the evaporation was neglected, and notice any interventions or diversions that branched from the reach.

The discharge of Hilla main canal and three distributary canals (HC 4R, HC 5R and HC 6R) was measured through the period of study by measuring the depth of water in the canals and then using the Bentley Flow Master V8i program to calculate the discharge for two depth using the canals properties.

3. Methods of Seepage Losses

The correct estimate of the loss of water transport is vital for the proper management of the irrigation system. The seepage is the important process which mean water is lost from the canal. The forecasting of the seepage is important for effective operation planning and management of an irrigation system.

There are two methods to estimate or measure the seepage of water from irrigation canals in field: inflow-outflow method and ponding method, and in the following the description for each method and how conducting these methods. Also there are two empirical equations (Davis and Wilson formula and Moritz Formula) to estimate the amount of seepage losses from the lined canals.

3.1 Inflow-Outflow Method

This method illustrates the losses that occur during conveyance of water in the open canals and are made without obstruction the operation of selected canal and additionally give measurements accurate enough (Akkuzu et al., 2007).

The inflow-outflow method uses to determining the amount of seepage losses and consists of measuring the inflow to and outflow from the reach of the irrigation canal and calculating the difference between them, and this method adapts with the long canals have a few number of diversions, and also uses with small sections of the canal which has the high seepage (Robinson and Rohwer, 1959).

When using the inflow-outflow method the measurements are carried out at one time so that the evaporation losses are neglected (Sunjoto, 2010). The amount of evaporation from the open surface of water is a small, so neglected and losses occurring in the canal segment are all consisted from the seepage (Akkuzu, 2012). In generally the evaporation loss in irrigation networks is not taken into consideration (Saeed and Khan, 2014).

3.2 Ponding Method

The seepage losses is measured in this method by booked the water in canal to the operational depth approximately and then measure the reduction in the surface of the water with time, and the losses are calculated by dividing the low volume of water to the time. This method is considered more accurate, but it is conducted with the obstruction of operational process of canal about two weeks, and the measurements must be made on the main canals either before or after the irrigation season (Worstell, 1976).

- The obstruction of operational process of canal is the reason of selected the inflow-outflow method in this study to measure the conveyance losses (seepage and operational losses from distribution systems) for Hilla main canal (lined canal) and three distributary canals (HC 4R, HC 5R and HC 6R) taking into consideration all watercourses branching ones, which are considered diversions.

- To determine the conveyance water losses (transmission losses) by the inflow-outflow method using the flowing equation (Abid, 1995):

$$Q_{tl} = Q_{loss} = Q_{in} - Q_{out} + Q_{int} - Q_{div} \quad \ldots (1)$$

Where:

$Q_{loss}=Q_{tl}$: Transmission losses or conveyance losses (m^3/s),
Q_{in}: Inflow to the reach (m^3/s),
Q_{out}: Outflow from the reach (m^3/s),
Q_{int}: Intervening inflow (m^3/s), and
Q_{div}: Total of diversions from the reach (m^3/s).

- The water losses percentage is given by the following equation (Saeed and Khan, 2014):

$$\text{Water loss percentage} = \frac{Q_{tl}}{Q_{in}} * \% \quad \ldots (2)$$

- The conveyance water losses can be calculated by the following equation (Abid, 1995):

$$\text{water losses} = \frac{Q_{tl}}{WP_{avg} * L} \quad \ldots (3)$$

Where:

L : Reach length (m).
WP_{avg} : Average wetted perimeter (m).

3.3 Empirical Formulas

Two empirical formulas are used to estimate the seepage losses from lined canals:

3.3.1 Moritz Formula

Moritz proposes equation for estimating the seepage losses from lined and unlined canals (Akkuzu, 2012):

$$S = 0.037 * C * \frac{Q}{V} \quad \ldots (4)$$

Where:

S: Seepage losses ($m^3/s/km$).
Q: Discharge of inflow in canal (m^3/s).
V: Velocity of inflow in canal (m/s).
C: Constant value depending on soil types. For concrete-lined canals, C was taken to be equal (0.1).

3.3.2 Davis and Wilson Formula

These authors suggest the following formula to estimate the seepage losses in lined canals (Akkuzu, 2012):

$$S = 0.45 * C * \frac{P_w * L}{4 * 10^6 + 3650\sqrt{v}} * H_w^{1/3} \quad \ldots (5)$$

Where:

S: Seepage losses (m^3 per length of canal per day).
L: Length of the reach (m).

P_w: Average wetted perimeter (m).
H_w: Water depth in the canal (m).
V: Velocity of inflow in the canal (m/s).
C: Constant value depending on lining. For concrete-lined canals, C was taken equal to (1).

4. Conveyance Efficiency

To find out the efficiency of the canals grid to conveyance water and delivered to the farms or fields, is used the conveyance efficiency.

Conveyance efficiency may be defined as the percentage ratio between the water flows out of the canal and water flows into the canal (Abid, 1995).

5. Results and Discussions

This reserch was compared the measured seepage losses from the Hilla main canal and three distributary canals that branched from Hilla main canal (HC 4R, HC 5R and HC 6R), all these canals are concrete lined canals with losses from the same canals that were estimated by using Moritz and Davis-Wilson equations, Depending on the depth of water, the calculated discharge and the properties of theses lined canals that entered in this research as shown in two Tables (Table (1) and Table (2)).

Table (1) the measured depth of water and the discharge for two reaches on Hilla main canal during months (Dec., Jan., Feb. and Mar.)

The Month	Reach No.	Canal name	Reach length (m)	Water depth (m)	Flow velocity of inflow (m/s)	Average wetted perimeter (m)	Discharge of inflow (m^3/s)	Discharge of outflow (m^3/s)
Dec.	1	Hilla main canal	300	2.00	0.51	9.620	5.63	5.35
	2	Hilla main canal	1000	2.08	0.52	9.910	6.12	5.81
Jan.	1	Hilla main canal	300	2.13	0.53	10.130	6.43	6.24
	2	Hilla main canal	1000	2.13	0.53	10.060	6.43	5.99
Feb.	1	Hilla main canal	300	2.33	0.56	10.850	7.77	7.56
	2	Hilla main canal	1000	2.35	0.56	10.850	7.91	7.42
Mar.	1	Hilla main canal	300	2.13	0.53	10.110	6.43	6.18
	2	Hilla main canal	1000	2.17	0.54	10.220	6.68	6.30

Table (2) the measured depth of water and the discharge for three reaches on three distributary canals (HC 4R, HC 5R and HC 6R) during months (Dec., Jan., Feb. and Mar.)

The Month	Reach No.	Canal name	Reach length (m)	Water depth (m)	Flow velocity of inflow (m/s)	Average wetted perimeter (m)	Discharge of inflow (m^3/s)	Discharge of outflow (m^3/s)
Dec.	3	HC 4R	1000	0.90	0.43	4.340	0.98	0.85
	4	HC 5R	500	0.68	0.48	2.930	0.53	0.42
	5	HC 6R	300	0.80	0.40	4.010	0.77	0.70
Jan.	3	HC 4R	1000	0.98	0.45	4.610	1.17	1.01
	4	HC 5R	500	0.86	0.54	3.590	0.89	0.75
	5	HC 6R	300	0.88	0.42	4.280	0.94	0.83
Feb.	3	HC 4R	1000	0.88	0.42	4.230	0.94	0.77
	4	HC 5R	500	0.86	0.54	3.580	0.89	0.73
	5	HC 6R	300	1.01	0.46	4.750	1.25	1.13
Mar.	3	HC 4R	1000	0.81	0.41	3.960	0.79	0.63
	4	HC 5R	500	0.68	0.48	2.930	0.53	0.42
	3	HC 6R	300	0.89	0.43	4.340	0.96	0.88

5.1 Seepage Losses from Hilla Main Canal

The measurements were conducted for seepage losses along a total of 1300 m in two reaches of Hilla main canal. According to measurements as shown in Table (1), water depth was varied from 2.00 m to 2.35 m, average wetted perimeter was varied from 9.620 m to 10.850 m, and canal flow was between 5.63 m3/s and 7.91 m3/ s.

Seepage losses occurring in Hilla main canal were found to vary between 31.28 $m^3/s/10^6m^2$ and 97.02 $m^3/s/10^6m^2$, with an average of 57.98 $m^3/s/10^6m^2$ for the two reach on canal and for four month, as shown in Table (3). Seepage values were shown a significant change in their amount, and the standard deviation was found 22.98 $m^3/s/10^6m^2$.

Depending on the hydraulic parameters of reach that selected from the Hilla main canal canals, the seepage was calculated using Mortiz and Davis-Wilson equations. The results for Mortiz equation was ranged between 4.25 $m^3/s/10^6m^2$ to 4.82 $m^3/s/10^6m^2$ with the average 4.5 $m^3/s/10^6m^2$. The results for Davis-Wilson equation were ranged between 0.00000160 $m^3/s/10^6m^2$ and 0.00000173 $m^3/s/10^6m^2$ with the average 0.00000168 $m^3/s/10^6m^2$. The estimated values of seepage losses by Mortiz and Davis-Wilson equations were found lower than the measured seepage losses values.

Table (3) Measured and Estimated Seepage Losses in the Hilla Main Canal

The Month	Reach No.	Conv. losses (m^3/s)	Water losses (actual) %	Measured seepage losses ($m^3/s/10^6m^2$)	Estimated seepage losses	
					Moritz equ. ($m^3/s/10^6m^2$)	Davis-Wilson equ. ($m^3/s/10^6m^2$)
Dec.	1	0.28	4.97	97.02	4.25	0.00000164
	2	0.31	5.07	31.28	4.39	0.00000166
Jan.	1	0.19	2.95	62.52	4.43	0.00000167
	2	0.44	6.84	43.74	4.46	0.00000167
Feb.	1	0.21	2.70	64.52	4.73	0.00000173
	2	0.49	6.19	45.16	4.82	0.00000173
Mar.	1	0.25	3.89	82.43	4.44	0.00000167
	2	0.38	5.69	37.18	4.48	0.00000168
Average				**57.98**	4.50	0.00000168
Std.				**22.98**		

5.2 Seepage Losses from Distributary Canals (HC 4R, HC 5R and HC 6R) Canals

The measurements were conducted for seepage losses in three reaches of the three concrete-lined trapezoidal section distributary canals that branched from Hilla main canal. According to measurements as shown in Table (2), water depth was varied from 0.68 m to 1.01 m, average wetted perimeter was varied from 2.930 m to 4.750 m, and canal flow was between 0.53 m3/s and 1.25 m3/ s.

Seepage losses occurring in distributary canals was found to vary between 11.82 $m^3/s/10^6m^2$ and 85.67 $m^3/s/10^6m^2$, with an average of 39.52 $m^3/s/10^6m^2$ for the distributary canal and for four month, as shown in Table (4). The standard deviation was found 27.96 $m^3/s/10^6m^2$.

Depending on the hydraulic parameters of reach that selected from the distributary canals, the seepage was calculated using Mortiz and Davis-Wilson equations. The results for Mortiz equation was ranged between 1.39 $m^3/s/10^6m^2$ to 2.12 $m^3/s/10^6m^2$ with the average 1.81 $m^3/s/10^6m^2$. The results for Davis-Wilson equation were ranged between 0.00000114 $m^3/s/10^6m^2$ to 0.00000131 $m^3/s/10^6m^2$ with the average 0.00000123 $m^3/s/10^6m^2$. The estimated values of seepage losses by Mortiz and Davis-Wilson equations were found lower than the measured seepage losses values.

Table (4) Measured and Estimated Seepage Losses in the Distributary Canals (HC-4R, HC-5R and HC-6R)

The Month	Reach No.	Conv. losses (m^3/s)	Water losses (actual) %	Measured seepage losses ($m^3/s/10^6m^2$)	Estimated seepage losses	
					Moritz equ. ($m^3/s/10^6m^2$)	Davis-Wilson equ. ($m^3/s/10^6m^2$)
Dec.	3	0.09	9.18	20.74	1.94	0.00000126
	4	0.08	15.09	54.61	1.39	0.00000114
	5	0.07	9.09	58.19	1.78	0.00000121
Jan.	3	0.06	5.13	13.02	2.09	0.00000129
	4	0.06	6.74	33.43	1.70	0.00000124
	5	0.11	11.70	85.67	1.93	0.00000125
Feb.	3	0.05	5.32	11.82	1.96	0.00000125
	4	0.04	4.49	22.35	1.70	0.00000124
	5	0.12	9.60	84.21	2.12	0.00000131
Mar.	3	0.06	7.59	15.15	1.80	0.00000121
	4	0.02	3.77	13.65	1.39	0.00000114
	3	0.08	8.33	61.44	1.90	0.00000125
Average				39.52	1.81	0.00000123
Std.				27.96		

- Measured losses, results of Mortiz equation and Davis-Wilson equation for maximum and minimum flow for Hilla main canal were compared as shown in Figure (6) and three distributary canals (HC 4R, HC 5R and HC 6R) were compared as shown Figure (7).

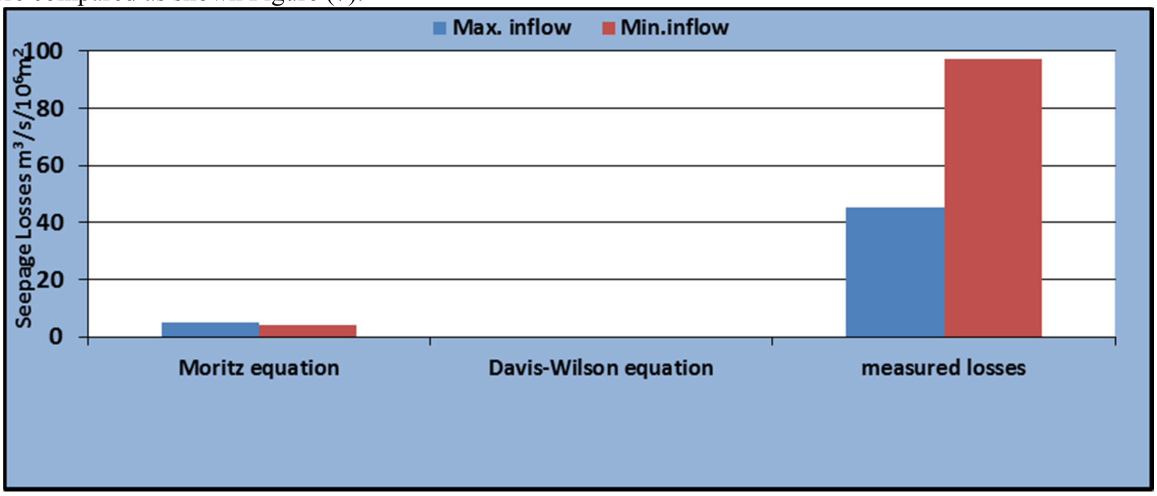

Figure (6) shows the comparison between measured losses, results of Mortiz and Davis-Wilson equation for Hilla main canal

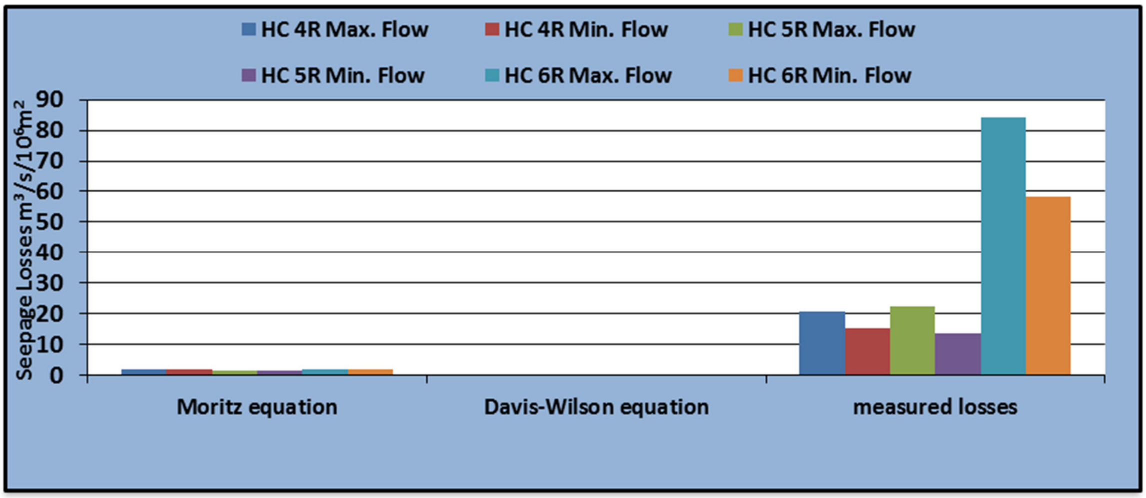

Figure (7) shows comparison between measured losses and results of Mortiz and Davis-Wilson equation for three distributary canals (HC 4R, HC 5R and HC 6R)

- When comparing the results found that in the month of February, the ration was for the second sector of Hilla

main canal (HC 5R and HC 6R) this means that the first sector (HC 4R) not have a full depth only water to drink so the seepage losses was measured (11.82 $m^3/s/10^6m^2$) and considered the least seepage losses for this canal.
According to the discharge of (HC 5R) was in the first months (Dec., Jan. and Feb.) the biggest of the design discharge and attributed this to:
1. The gate of canal was opened higher than the design limit.
2. Due to lack of maintenance and cleaning of the canal from sediments mud and Ceratophyllum demersum so that the water depth was increased. In the month of March, this canal was cleaned from sediments mud and Ceratophyllum demersum by the management of the project, and thus the water depth was decreased and the design discharge was achieved and given the less seepage losses compared to the other months due to normal depth.
The USBR considers 0.002 $m^3/day/\ m^2$ (about 0.02 $m^3/s/10^6m^2$) as a design standard of seepage rate for concrete lined canals (Kishel, 1989).
Labye et al., (1988) found that the seepage rates for lined canals 30 mm/day (about 0.3 $m^3/s/10^6m^2$) and for unlined canals in sands or gravels was 20 times the value or more for lined canals.
When calculation the seepage losses per unit area and according to wetted perimeter and the length of the reach were found that the average of seepage losses in concrete lined and trapezoidal section for Hilla main canal (57.98 $m^3/s/10^6m^2$) and for distributary canals (39.52 $m^3/s/10^6m^2$).
When compared with design standard showed that the seepage losses are much higher than it, the reasons of that maintenance of the project is inadequate where there are collapses and cracks in lining layers and lack maintenance of the lining joints as shown in Photo (1).

Photo (1) collapses and cracks in the layers of lining of Hilla main canal

5.3 Conveyance Efficiency
The conveyance efficiency was evaluated of the study area, which includes Hilla main canal and three distributary canals (HC 4R, HC 5R and HC 6R) within Hilla-Kifil project for a period of four months and compared the average of values with the design conveyance efficiency as shown in Table (5).

Table (5) the comparison between the average conveyance efficiency with its design value

Canal name	Hilla main canal	4R	5R	6R
The average Conveyance efficiency (%)	95.21	83.68	81.20	90.33
Design Conveyance efficiency (%)	100	100	100	100

6. Conclusions

1. Seepage losses that obtained in Hilla main canal and three distributary canals (HC 4R, HC 5R and HC 6R) were above standard and there was a large difference between them due to cracks and collapses in layer lining which due to inadequate the maintenance and the asphaltic mastic at the joints of the lining deteriorated. Estimated losses by Davis and Wilson equation were less than the minimum but it was far below the measured, so can be said this equation not be relied upon estimation seepage losses in lined concrete canals.
2. The water conveyance efficiency was less than the design values because of the deterioration of the project canals.

7. References

Abid, M. B., (1995), "*Evaluation of Irrigation System in Abu-Ghraib Project*". M. Sc., Thesis, College of Engineering, University of Baghdad, Iraq.
Akkuzu, E., (2012), "Usefulness of Empirical Equations in Assessing Canal Losses through Seepage in Concrete-Lined Canal", *Journal of Irrigation and Drainage Engineering*, ASCE, ISSN: 0733-9437, **138** (5), 455-460.

Akkuzu, E., Unal, H. B., and Karatafi, B. S., (2007), "Determination of Water Conveyance Loss in the Menemen Open Canal Irrigation Network", *Turkish Journal of Agriculture and Forestry* (Turk J Agric For), 31 (2007), 11-22.

"Feasibility Report of Hilla-Kifil Project", Hilla-Kifil Irrigation Project Management, July, (1980).

Kishel, J., (1989), "Seepage and Contraction Joints in Concrete Canal Linings", *Journal of Irrigation and Drainage Engineering*, ASCE, **115** (3), 377-383.

Labye, Y., Olson, M.A., Galand, A., and Tsiourtis, N., (1988), "*Design and Optimization of Irrigation Distribution Networks*", FAO Irrigation and Drainage, Paper 44, Rome.

Maghrebi, M. F., Azad, D., Mousavi, S. H., and Kazeran, H. S., (2011), "Estimation of Water Leakage from Seams and Cracks of Concrete Lined Canals" International Commission on Irrigation and Drainage, ICID21st Congress, Tehran**.**

Robinson, A. R., and Rohwer, C., (1959), "Measuring Seepage from Irrigation Channels", Technical Bulletin No. 1203, agriculture research service, United States Department of Agriculture, Washington, D.C., 82p.

Saeed, T. U. and Khan, T. A., (2014), "Impact of Water Losses and Maintenance of Canal Irrigation System on Agriculture (Case Study: Urmar Minor of Warsak Gravity Canal Pakistan)", *American Journal of Experimental Agriculture*, **4** (5), 550-562.

Sunjoto, S., (2010), "Irrigation Canal Water Losses", *Journal of Environmental Hydrology*, **18** (5), 1-14.

Worstell, R. V., (1976), "Estimating Seepage Losses from Canal Systems", *Journal of the Irrigation and Drainage Division*, **102** (IR1), 137-147**.**

Yaragatti, S. L., (1982), "*Linings for Canals*", M. Sc. Thesis, Department of Civil Engineering, Kansas State University, Manhattan, Kansas, USA.