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Evaluation of An Irrigaton Project; A Case Study the C10 Canal Part of Al Khachiya Irrigation Project

Othman T. Tuman[1] and Riyadh Z. Azzubaidi*[2]

[1] *Department of Water Resources Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq, Osman.tuman2110m@coeng.uobaghdad.edu.iq*

[2] *Department of Water Resources Engineering, College of Engineering ,University of Baghdad, Baghdad, Iraq, riyadh.z.azzubaidi@coeng.uobaghdad.edu.iq.*

** Corresponding author: Riyadh Z. Azzubaidi and email: riyadh.z.azzubaidi@coeng.uobaghdad.edu.iq.*

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Abstract— Due to the fact that Iraq is one of the most affected countries, the increase in population growth and the detrimental effects of global warming, along with the neighboring countries' exploitation of transboundary rivers, have resulted in severe water resource shortages and detrimental effects on the environment, society, and economy. One of the most significant projects is the Al Khachiya Irrigation Project, which is extended 55 kilometers to the left of the Tigris River in the Iraqi province of Wasit. It serves an area of roughly 55.8 km². We chose three fields A1, A2, and A3 to assess the Al Khachiya Irrigation Project. The C10 Canal, which is 18.9 km in length and designed to pass an estimated 19.5m³/s, is a component of the Al Khachiya Irrigation Project. A few specifically selected performance measures, such as the effectiveness of water application, storage, and distribution, water conveyance, and overall canal efficiency, were used to evaluate the C10 Canal. The C10 Canal is being evaluated using the A2, A3 fields.The average water application efficiency for the A2 and A3 fields, according to the results is 37.09 % and 46.45 % respectively. In other words, farmers utilize more water than is actually needed. Water storage efficiency is 67.94% and 53.13% for fields A2 and A3 respectively, on average. Moreover, the water distribution efficiency is approximately 92.29% for A2 field and 91.05% for A3 field. According to field measurements, the water conveyance efficiency of C10 Canal is 93.62 **%,** cracks are observed in some lining boards of C10 canal, which affected the convenience efficiency**.** The overall efficiency of C10 Canal is 35.85%. The results of evaluation showed that more losses of water were caused by inefficient use, longer operating hours, and a lack of knowledge and expertise among farmers regarding water management.

Keywords— Moisture content, Water application efficiency, Water Distribution efficiency, Irrigation efficiency, Water Storage efficiency .

1. Introduction

In general, the scarcity of water in the Tigris River is a result of a deficiency in the water resources that feed the river, and climate change combined with rising water demand brought on by population expansion makes water management vital. The number of dams being built in Iran and Turkey has reduced the amount of water entering the border [1], and due to a lack of rainfall, this issue will only get worse in the future [7]. All rivers and wadies have discharges ranging from 0 to 888.8 m³/s [5]. A combination of all of these factors, the decision-makers involved in irrigation projects in Iraq are forced to re-evaluate how they manage water resources. They examine the irrigation projects, determine the amount of water lost, and determine the most effective way to prevent these losses through the use of contemporary irrigation systems and land cultivation techniques. Since most irrigation projects, especially large-scale projects, are not working up to par, it is imperative to assess the effectiveness of water application on land in order to calculate the amount of water lost and the real water supply [3]. In order to optimize irrigation water utilization and reach a strategic goal for water management, action must be taken by applying contemporary irrigation techniques, technologies, and agricultural procedures [8]. As a result, it's critical to use irrigation water as efficiently as possible to ensure both long-term economic benefits and the availability of irrigation water; irrigation systems with high efficiency outperform those with low efficiency [12]. Optimal crop water management is necessary to sustain agricultural output and increase sustainability [20]. The Al Khachiya Irrigation Project is chosen for assessment, and its overall efficiency is determined by measuring the effectiveness of the project's water storage, distribution, and irrigation applications. Water distribution guidelines and irrigation efficiency have lately grown in importance as development devices for agriculture. Assessing the effectiveness of irrigation projects gave stakeholders a hands-on understanding of how the system functions and what has to be improved for it to become more effective. Assessing the irrigation system's performance demonstrated to stakeholders how things should be done in order for them to function properly [12]. By gathering information, measuring the discharge and water applied depth, and determining the required net depth, the study aims to estimate the water losses inside the fields of the Al Khachiya Irrigation Project and determine the water application efficiency to the irrigation surface system (furrows and borders). Next, offer ideas for improving the system's water irrigation efficiency.

2. IRRIGATION EFFICIENCIES

Not all of water drawn from a well or river reaches the crop's root zone. A portion of the water may be wasted in the fields and during canal transportation. The root zone stores the remaining water. Put another way, whereas just a little of water is used effectively, some water that was intended for irrigation is lost. The ratio of water used for actual plant growth requirements to water from the source is known as irrigation efficiency [2]. Distribution, conveyance, and field application efficiency are all components of irrigation efficiency [14].

2.1 *Distribution efficiency*

The uniformity of the water distribution at the root zone region is referred to as distribution efficiency. Water for crops was once distributed and stored by it. To calculate distribution efficiency quantitatively is written as:

$$E_d = (1-y/d) \quad (1)$$

where : E_d is distribution efficiency; **d** is water stored depth; and **y** represents the average deviation from the average depth of water stored depth.

2.2 *Water aplication efficiency*

The ratio of the water depth of a root zone to the overall depth of water delivered in the field is known as application efficiency or water use efficiency. The expression for application efficiency is:

$$E_a = \frac{dn}{dg} x\,100 \ \% \quad (2)$$

where: E_a is Application Efficiency in fields (%); d_n is the water depth (mm) inside the rootzone;; and d_g is applied the entire water depth (mm).

2.3 *Moisture content and water stored depth*

The moisture content was determined using the following formula. [17]:

$$p_w = \frac{w_w}{w_s} x100 \ \% \quad (3)$$

where: p_w is weight moisture content; w_s indicates the soil's solid weight; and w_w is the weight of water.To obtain the moisture content (by volume), can make use of the subsequent formula:

$$P_V = P_W \ x \ A_S \quad (4)$$

where: P_V is the volumetric moisture content;and A_S is the specific gravity of soil.

The following expression can be used to determine the depth of water stored:

$$d = \frac{P_w}{100} x \ A_s \times D \quad (5)$$

where: **d** is the net depth of water before and after irrigation ; **D** is the depth of root zone.

2.4 *Conveyance efficiency*

The ratio of the water in the canal from the pumping station or reservoir to the water in the distribution offtakes of canal is known as the conveyance efficiency. The formula for conveyance efficiency is:

$$E_c = \frac{Q_2}{Q_1} x\,100 \ \% \quad (6)$$

where: E_C is the Conveyance efficiency(%),Q_1 is the water entering (m^3/s); and Q_2 is the water delivered the system (m^3/s) [13].

2.5 *Efficiency of water storage*

The ratio of the depth of water storage in root zone to the depth of water required by plant is knowing water storage efficiency and it is expressed as:

$$E_s = \frac{d_n}{d_s} x\,100 \ \% \quad (7)$$

where: E_s is the water storage efficiency(%); and d_s is the depth of water that a plant requires when getting irrigation (mm) **FAO, 1989**[10].

2.6 *Overall irrigation efficiency*

The average efficiency of all activities between the plant root zone and river diversion is represented by the term "Overall Irrigation Efficiency" (Ep). Total effectiveness can be stated as:

$$E_p = E_a . E_d . E_c \tag{8}$$

3. FIELD WORK

Below are the most important requirements for conducting field work, as follows:

3.1 *The Research Field*

Al Khachiya Irrigation Project is located in the central region of Iraq, north of the Wasit Governorate, and marks the administrative boundary between Baghdad and the governorate. The project region is situated between latitudes 33°01′ 51′ and 33°06′ 15′ and longitudes 44°44′ 11′ and 44°56′ 15′. The project has a gross area of 279 km2, of which around 216.5 km2 is irrigated. The highest amount of rainfall that January will see. Given that a mean yearly observed in the project of 170 mm, where managing the available water requires a close relationship between rainfall and runoff **[9].** The temperature ranges for the minimum and maximum were, respectively, 3.8-26.4 °C and 16.7-49.5 °C. The lowest wind speed was 1.89 m/s in December, while the highest was 3.3 m/s in March. The observed sunlight hour shows a significant range (6.5–12.5). There is loam and silt loam in the project's soil. 61% of the total precipitation is lost through evaporation **[6]**. Surface and pump irrigation (border and furrow) are the irrigation techniques employed in this project. The principal irrigation system in the Al Khachiya project is comprised of distributary canals with watercourses and a main canal. Al Khachiya Project and all other agricultural lands and irrigation supplies are under the supervision of the water resources directorate of the Wasit governorate. **Figure.1**: Al Khachiya Project irrigated land.

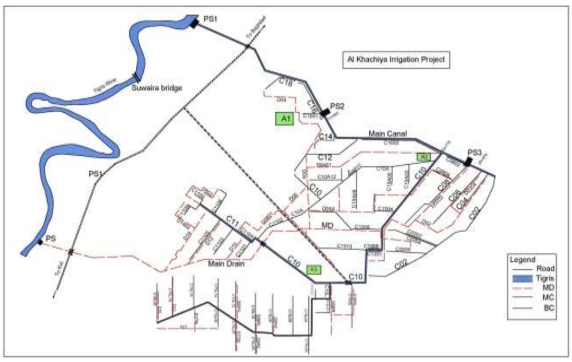

Figure 1: Al Khachiya Irrigation Project and its branches are organized.

3.2 *Determined Fields within the Field of Study*

An assessment of C10 Canal Determining the true irrigation effectiveness of the lands that get water from Al Khachiya Irrigation Project is one of its components. To get the information required to assess and enhance the system and look into the hydraulic system inside the zone, fieldwork is crucial [4]. As indicated in **Table.1**, the fields were chosen to assess the irrigation performance within the project. It is irrigated by C10 Canal, and in order to ensure measurement accuracy, it was divided into three sections. Before and after irrigation, the moisture content was measured to determine the actual depth of water required by the crop, the depth of water applied, and the amount of water lost.

Table 1: Location of the A2 and A3 fields in the research area.

No.	Canal Name	Field	Station Km	UTM Coordinates	
				Easting	Northing
1	C10 Canal	A2	23+240	33º11′41″	44º50′35″
2	C10 Canal	A3	41+325	33º07′14″	44º56′42″

3.3 *Physical Properties of Soil*

A crucial factor in determining how well an irrigation project performs is the properties of the soil. The evaluation includes data on the following: bulk density soil, soil texture, PH, EC, field capacity (FC), permanent wilting point (PWP), and the contents of magnesium, sodium, and calcium. For the field, soil samples were collected between 0 and 80 cm deep in order to cover the root zone and determine how the characteristics of the soil varied between layers. The soil analysis conducted at the laboratory of college of Agriculture/University of Baghdad. Only the bulk density was ascertained in the field using the core; all other physical parameters have been confirmed in the lab. The soil characteristics laboratory results appear in **Table.2.**

Table 2: The laboratory results of soil characteristic.

Field	Depth of soil sample *cm*	Soil texture	F.C by vol. %	wilting point by vol. %	EC *ds/m*	PH	Ca^+ *mg/l*	Mg^+ *mg/l*	Na^+ *mg/l*
A2	0-40 40-80	Loam	30	14.8	6.7	7.25	26.01	13.91	5.82
A3	0-40 40-80	Silt Loam	30.4	18.8	1.2	7.22	5.31	3.92	1.42

3.4 *Discharge Measurment*

To be able to assess the discharge, a venturi flume was placed at the entrance of the canal specified for the field. This open flume has a limited flow and a critical flow, which results in a critical depth due to a dip in the hydraulic grade line [*19*] A venturi flush includes:

A- A 40 cm expansive portion upstream converges consistently.

B- A 20 cm-wide short neck portion.

C- The downstream segment diverges consistently to a width of 40 cm.

D- There is a level surface all the floor area.

E- Its composed of stainless steel and measures 40 cm in height and 1.5 meters in total length.

$$Q_C = C B_2 y_2 \sqrt{\frac{2gH}{1-\left(\frac{B_2 y_2}{B_1 y_1}\right)^2}} \quad (9)$$

Where: Q_C = discharge (m^3/sec).

C= Coefficient of discharge.

B_1= Upstream width (m). and B_2 =Throat width (m).

y_1= Upstream depth (m). and y_2= Throat depth (m).

H= Difference depth (y_1- y_2).

Figure 2: Screenshots taken when use the venturi flume.

3.5 *Depth of Root Zone*

The root depth of wheat crop will be computed, By gently excavating the dirt surrounding the roots of crop without scratching them, one can roughly determine the root depth (vertical). With every irrigation, the root depth is determined using a tape measure. Soil water depletion fraction (AD) and root depth as reported by **FAO 1989[**10]are indicated. **Table 3** and **Table 4**.show the root depth of crop for A2, A3 fields.

Table 3: Measuring Root Zoon depth of crop for A2 field.

Date	Canal name	Crop type	Average root depth, cm
Jan-4, 2023			20
Feb- 8, 2023	C10	Wheat	35
Mar-6,2023	canal		50
Apr-8, 2023			68

Table 4: Measuring Root Zoon depth of crop for A3 field.

Date	Canal name	Crop type	Average root depth *cm*
Jan- 2, 2023			20
Feb- 2, 2023	C10	Wheat	35
Mar-3,2023	canal		50
Apr-6, 2023			68

3.6 *Applied Water Depth*

The volume of applied water is determined from the product of the discharge during irrigation to determine the depth of the applied water; the depth of the applied water is then found by dividing the volume of applied water by the area of the field. The applied water depths for A2, A3 fields are displayed in **Table 5**.and **Table 6**. The depth of applied water, stored water, and lost water are shown in **Fig. 3** and **Fig. 4**. Where the depth of water kept in the A2 field is 24.91 mm, the average applied depth of water is 67.03 mm, and the deep percolation depth is 34.42 mm, representing approximately 51.3% of the water lost in the field. And the depth of water kept in the A3 field is 18.35 mm, the average applied depth of water is 41.29 mm, and the deep percolation depth is 22.93 mm, representing approximately 55.5% of the water lost in the field.

Table 5: The applied water depth measurement of A2 field.

Date	Flow rate *lps*	Time of irrigation *Hours*	applied water m^3	Net Area *dounm*	Depth of water applied *mm*
Jan- 2, 2023	19.1	16	1100.16	8	55
Feb- 2, 2023	19.1	18	1237.68	8	61.88
Mar-3,2023	19.1	20	1375.2	8	68.76
Apr-6, 2023	19.1	24	1650.24	8	82.51

Table 6: The applied water depth measurement of A3 field.

Date	Flow rate *lps*	Time of irrigation Hour	applied water m^3	Net Area *dounm*	Depth of water applied *mm*
Jan- 4, 2023	15.5	7	390.6	5	31.25
Feb- 8, 2023	15.5	8	446.4	5	35.71
Mar-6,2023	15.5	10	558	5	44.64
Apr-8, 2023	15.5	12	669.6	5	53.57

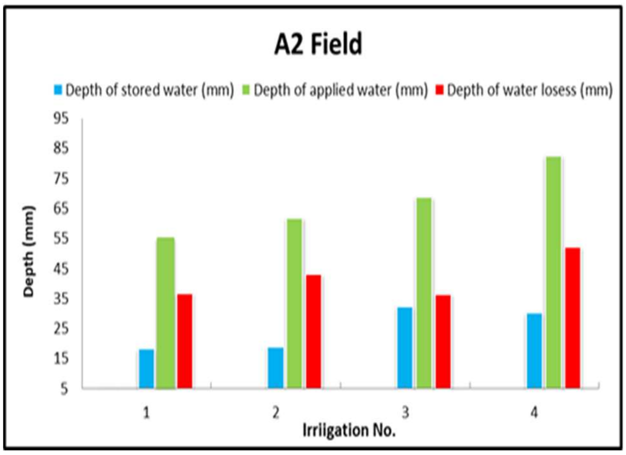

Figure 3: The depth of water lost throughout each watering of the A2 field, as well as the depth of water applied and stored.

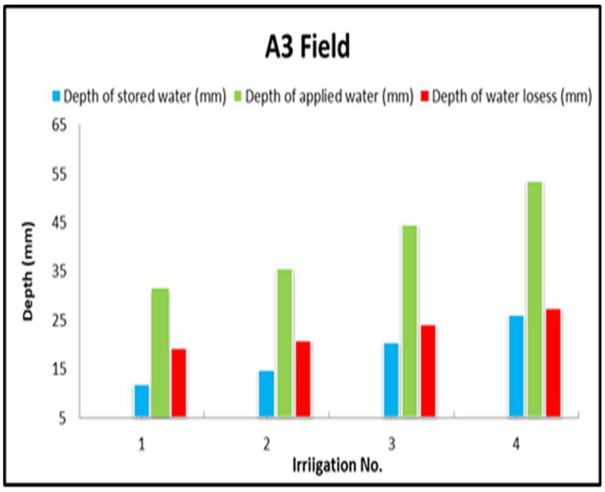

Figure 4: The depth of water lost throughout each watering of the A3 field, as well as the depth of water applied and stored.

4. RESULTS AND DISCUSSIONS

After completing the field work, we review the most important results obtained from the study and anlyze them as follows:

4.1 *Distribution and water storage efficiencies*

Because it depends on the type of irrigation technique utilized, such as surface irrigation, the water distribution and storage efficiencies in the research region are generally high. Water storage causes significant changes to groundwater-storing flood plains and wetlands by altering the timing, volume, and chemical makeup of a river's flow (Nama A., H., 2015). When more water is added to the field than is required, the amount of water is added, and the efficiency is calculated based on field data. For A2 and A3 fields the average value of water storage efficiency is 67.94% and 53.13% with a range of values from 45.25 to 78.95% and 48.29 to 59.84% receptively, although the irrigation project's water distribution efficiency is over 90% [15], deems it to be exceptional. This indicates a good, uniform distribution of moisture in the root zone, demonstrating a high degree of uniform plant growth. Additionally, as the high water storage efficiency falls between FC and PWP limits, it suggests that the plant is using the water stored in the soil to boost productivity. Distribution efficiency is 92.29%for A2 field and 91.05% for A3 field on average. The water distribution and storage efficiency in the A2 and A3 fields are shown in **Fig.5. And Fig.6**.

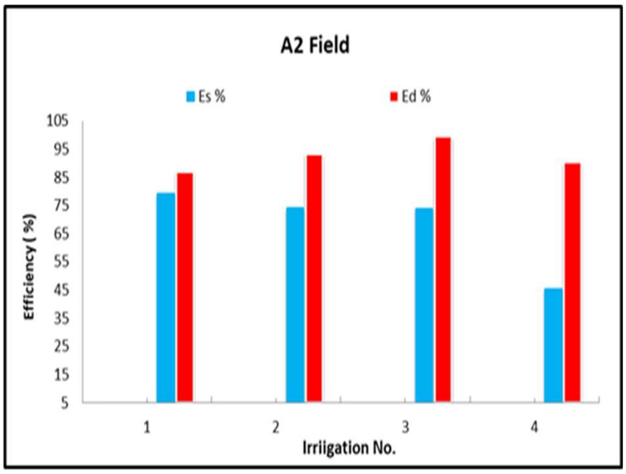

Figure 5: The efficiency of distribution and water storage for field A2.

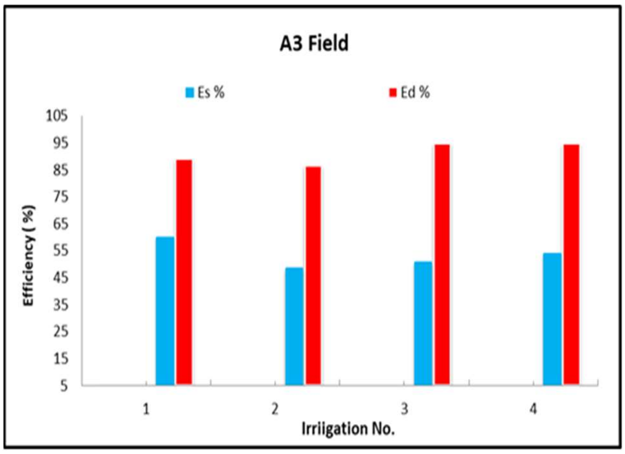

Figure 6: The efficiency of distribution and water storage for field A3.

4.2 *Water application efficiency*

The actual average of water application efficiency for each watering in A2 and A3 fields is approximately 37.09 % and 46.4 respectively, which is field A2 and A3 irrigated by borders. This efficiencies value is deemed without the range of water application efficiency 40% - 60% as specified by **FAO, 1995**[11]. The above results show that farmers use more water for irrigation than the plants actually require. Controlling the irrigation period allows you to improve application efficiency. **Figure 7** depicts the direction of the application efficiency curves for A2 and A3 fields at various irrigation times.

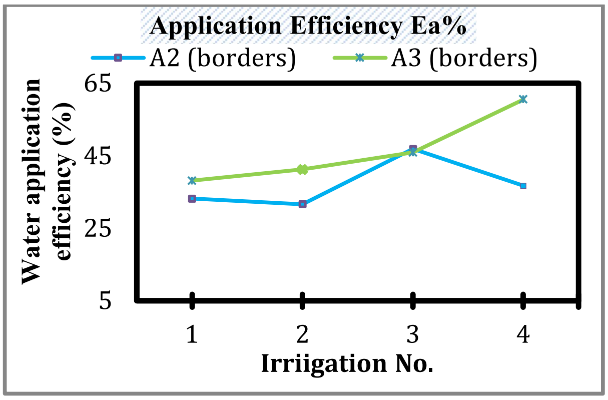

Figure 7: The direction of the application efficiency curves in A2 and A3 fields for various irrigation times.

4.3 *Moisture content and water stored depth*

Moisture content is a crucial factor in determining irrigation efficiency; it is monitored and documented on-site. This moisture content is monitored within the root zone before and after water application from December 29, 2022 to April 8, 2023 for various root depths. The wheat crop was planted as seeds on November 1, 2022, and was harvested on May 1, 2023. Figures 8, 9 depict the change in moisture content before and after irrigation for the field studies BMC and AMC, as well as the FC and PWP levels and the allowable depletion AD. The AD .FC and PWP are]10[is calculated using FAO, 1989 indicators of crop water availability. If the moisture content falls below PWP, the crop is unable to reach the water and the soil becomes dry.

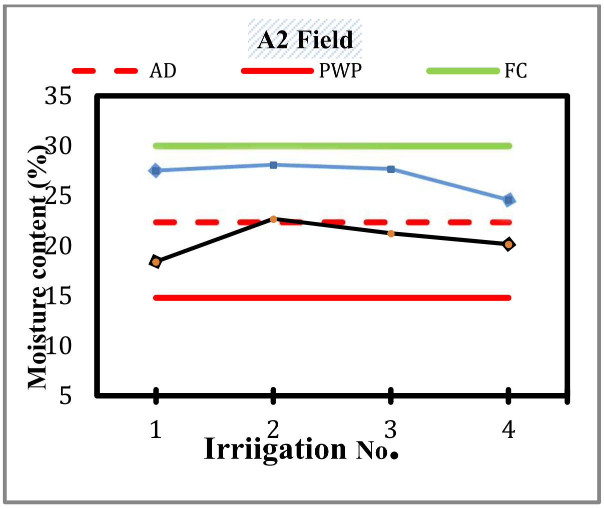

Figure 8: The moisture content of the effective root zone in A2 field.

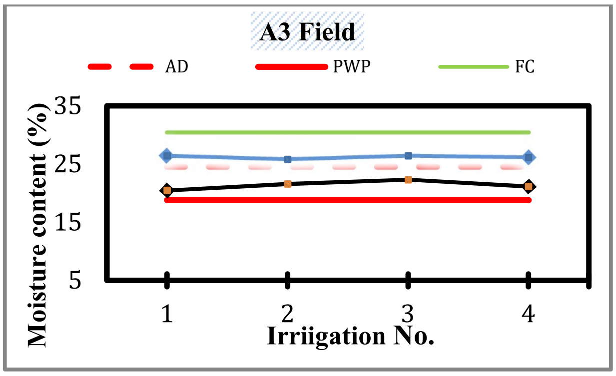

Figure 9: The moisture content of the effective root zone in A3 field.

4.4 *Conveyance efficiency*

The actual conveyance efficiency is measured in the C10 Canal to determine the amount of water lost due to seepage and evaporate from the surface of the water, so it is critical to determine the losses to know the real quantity of water provided to the field; it is verified in winter 2023 for the C10 Canal and the discharge is measured at stations 0+100 km and 18+986km and it is 18.76 m3/s and 17.57 m3/s respectively, as shown in **Table 7**. Thus, the water losses along this distance are 630 l/s (equal to 63 l/s/km length), or around 1.19 m3/s along the C10 Canal. So the conveyance efficiency is 93.62%, which is quite good for a lined canal **Halcrow, 1992**[12].

Table 7: The conveyance efficiency calculations for the C10 Canal.

No	station	Station *km*	Discharge *m^3/s*	Seepage losses *l/sec/km*	Conveyance efficiency %
1	M_1	00+100	18.76	63	93.62
2	M_2	18+986	17.57		

4.5 *Overall irrigation efficiency*

The average outcomes of water application, water distribution, and conveyance efficiencies must be computed in order to assess the overall effectiveness of the C10 Canal of the Al Khachiya Irrigation Project. The project's C10 canal's average irrigation efficiency is displayed in Table 8.

Table 8: The conveyance efficiency calculations for the C10 Canal.

Canal name	Field	AverageEa %	AverageEd %	Ec %	E_o %
C10 Canal	A2	41.77	91.67	93.6	35.85

A3	2

According to Table 8, the C10 Canal's overall efficiency is 35.85%. Because it is below the allowable limit, the total efficiency of C10 canal is low. This indicates that a flaw in the project' water management procedures is causing more water to leak out. Furthermore, more water that is required has been provided to the field. To enhance the project's water management, it is necessary to ascertain each plant's actual crop water requirements. These requirements include the amount of water that transpires from the plant, evaporates from the earth's surface, is consumed by the plant, is needed for washing, and is lost in the field as a result of irrigation. These requirements should be compared to the amount of water applied in order to prevent using too much water.

5. Conclusion

The irrigation efficiency results for the C10 Canal of the Al Khachiya Irrigation Project revealed that large amounts of irrigation water are lost through surface runoff and deep percolation as a result of farmers using more water for irrigation than is necessary, which results in poor water management. The percentage of water losses in the A2 field is 62.58% and 45.78% in A3 field. For this reason, it is critical to reevaluate the irrigation project's efficiency rather than relying solely on design standards to estimate water requirements. The main points are concluded below:

1. The average water application efficiency (border irrigation) is 37.09% and 46.45% for A2 and A3 fields respectively. Low application efficiency values result from both mistimed irrigation and overwatering plants relative to their needs. Reducing operation times and managing water properly in the fields can increase applicationefficiency.Requires rescheduling irrigation times according to the actual need for each field and using the water standard application in the project.

2. The study area uses surface irrigation, which involves completely submerging the field in water. This method increases storage and distribution efficiencies, but it also results in a high degree of moisture distribution homogeneity in the root zone at the cost of significant water loss from surface runoff and deep percolation. The efficiency of storage water for the two fields are 67.94% and 53.13% respectively . Additionally, 92.29% for A2 and 91.05% for A3 of the water is distributed efficiently.

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Nomenclature

AD	Allowable depletion, (%)
A	Net irrigation area,(L^2)
dg	Gross depth of applied water, (L)
dn	Net depth of Irrigation, (L)
Ec	Conveyance efficiency, (%)
Ed	Distribution efficiency, (%)
Es	Storage efficiency, (%)
Ea	Application efficiency, (%)
E_o	Overall Project efficiency, (%)
FC	Field capacity (% by volume).

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تقييم مشروع أروائي: حالة دراسية قناة C10 جزء من قناة مشروع الخاجية الأروائي

عثمان طارش تومان[1] رياض زهير الزبيدي[2]*

[1] *قسم هندسة الموارد المائية، كلية الهندسة، جامعة بغداد، بغداد، العراق، Osman.tuman2110m@coeng.uobaghdad.edu.iq*

[2] *قسم هندسة الموارد المائية، كلية الهندسة، جامعة بغداد، بغداد، العراق، riyadh.z.azzubaidi@coeng.uobaghdad.edu.iq*

* *الباحث الممثل: رياض زهير الزبيدي riyadh.z.azzubaidi@coeng.uobaghdad.edu.iq*

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الخلاصة – نظراً لكون العراق من أكثر البلدان تضرراً، فإن الزيادة في النمو السكاني والآثار الضارة للاحتباس الحراري، إلى جانب استغلال الدول المجاورة للأنهار العابرة للحدود، أدت إلى نقص حاد في الموارد المائية وآثار ضارة في البيئة والمجتمع والاقتصاد. ومع ذلك، فإن انخفاض كفاءة الري، وانخفاض هطول الأمطار، واستخدام المياه بهدر، يتطلب إعادة تقييم أنظمة الري وتعزيز فعاليتها. ومن أهم المشاريع مشروع ري الخاجية الذي يمتد مسافة 55 كيلومترا إلى يسار نهر دجلة في محافظة واسط العراقية. ويخدم أراضي زراعية تبلغ مساحتها حوالي 55.8 كيلومتر مربع. لقد اخترنا ثلاثة حقول A1 وA2 وA3 لتقييم مشروع ري الخاجية. وتزرع هذه الحقول بمحاصيل متنوعة وتستخدم تقنيات الري (الأخاديد والالواح).تعد قناة C10، التي يبلغ طولها 18.9 كيلومترًا ومصممة لتمرير تصريف ما يقدر بـ 19.5 مترًا مكعبًا في الثانية، أحد مكونات مشروع ري الخاجية. تم استخدام بعض مقاييس الأداء المختارة خصيصًا، مثل كفاءة استخدام المياه وتخزينها وتوزيعها وكفاءة نقل المياه والكفاءة الإجمالية لتقييم قناة C10. حيث يتم تقييم قناة C10 باستخدام الحقول A2 وA3. طوال العمل الميداني، تم إجراء قياسات وحساب السعة الحقلية ونقطة الذبول الدائم، وحساب التصريف الداخل الى الحقل باستخدام مسيل فنتشوري، وحساب عمق الجذر خلال موسم النمو. وكذلك تم تحديد محتوى الرطوبة قبل وبعد الري. لذا كان متوسط كفاءة تطبيق المياه للحقول A2 و A3 حسب النتائج هو 37.09% و 46.45% على التوالي. وبعبارة أخرى، فأن المزارعون يستخدمون كميات أكبر من المياه مما هو مطلوب بالفعل. تبلغ كفاءة تخزين المياه 67.94% و53.13% للحقول A2 وA3 على التوالي في المتوسط. علاوة على ذلك، تبلغ كفاءة توزيع المياه حوالي 92.29% للحقل A2 و91.05% للحقل A3. وفقاً للقياسات الميدانية فإن كفاءة نقل المياه الحقيقية لقناة C10 تبلغ 93.62%، وقد لوحظ تشققات في بعض الألواح المبطنة لقناة C10 مما أثر على كفاءة االنقل. تبلغ الكفاءة الإجمالية لقناة C10 35.85%. أظهرت نتائج تقييم قناة C10 لمشروع ري الخاجية أنه تم استخدام كميات أكبر من المياه مما كان ضروريًا، مما أدى إلى خسائر كبيرة في كميات المياه من خلال التغلغل العميق والجريان السطحي. وقد نتجت هذه الخسائر عن الاستخدام غير الفعال، وساعات التشغيل الطويلة، وقلة المعرفة والخبرة بين المزارعين فيما يتعلق بإدارة المياه.

الكلمات الرئيسية – المحتوى الرطوبي, كفاءة تطبيق المياه, كفاءة توزيع المياه, كفاءة الري, كفاءة خزن المياه.