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Estimation of Water Balance for the Central Basin of Erbil Plain (North of Iraq)

Abstract-*Erbil city located, in the northern part of Iraq, within the central basin of Erbil plain which covers an area about 1400 Km2 where Erbil city area measures about 70 Km2, is located between latitudes (36° 08 30″-36° 14 15″) north and longitudes (43 ° 57 '30 "- 44 ° 03' 20") east, The rocks exposures at the central Erbil plain date back to the (Upper Miocene-Recent) and this includes Ingana, Muqdadiya, Bai Hassan formations as well as Quaternary deposits. Tectonically, the studied area is located within Chumchamal-Butma Subzone at the area of the foothills. The movement of the groundwater in the study area is from the east to the west. Depending on the climatic data recorded in Erbil station for the period (1980-2016) shows that the total falling rain was (418.0) mm, and the temperature (15.81 ° C), relative humidity (29.96%), wind speed (1.94 m / s), solar brightness (8.28 hours / day) and the total evaporation from free surfaces was (1674.8 mm) the prevailing climate in the region is moist-humid to moist. corrected potential evapotranspiration was calculated theoretically apply Thornthwaite method where she was value 734.58 mm, was also calculate the water surplus, which accounted for 79.18% divided into surface runoff and its value 39.36 mm and Groundwater Recharge 87.82 while the water deficit represents 20.82% of the annual rainfall as the annual recharge rate was calculated for Erbil Central Basin and is reached 122.94 × 106 m3/year.*

Keywords- *water balance, Erbil, climate, evapotranspiration, water surplus, water deficit.*

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1. Introduction

Erbil basin is plain divided into three secondary basins: Kapran basin in the north and the central basin which includes Erbil city and Bash Tepa basin in the south. It is bounded on the upper and lower Zab River from the northwest and southeast respectively. The central basin area in about (1400 Km2), while the Erbil city area of about (70 Km2) is located between latitudes (36 08 30 - 36 14 15) north and longitudes (43 57 30 - 44 03 20) east Figure 1. The rock exposure at the central Erbil plain data back to the (Upper Miocene – Recent) and this includes Injana, Muqdadiya, Bai Hassan formations as well as Quaternary deposits. Tectonically, the studied area is located within Chumchamal-Butma Subzone at the area of the foot hills [2]. The movement of the groundwater in the study area from the east to the west is shown in Figure 2.

2. Method and Materials

The climatic data for the study area which covered the period (1980-2016) of Erbil meteorological station was drawn from the Iraqi Meteorological Organization [4], in order to determine the monthly mean values of climatic parameters, as shown in Table 1 and Figure 3. Thornthwiat equation was used to determine the values of the potential evapotranspiration. The water balance of the study area was calculated by using Lerner method, water surplus ratio from the yearly rainfall (Where the soil moisture considered =0) calculated as follows [5]:

WS % = WS/P ×100

While: WD% = 100 – WS%

In addition, two of the climate classifications were used to delineate the type of climate in the study area.

3. Results and Discussion

The monthly average values of climate parameters in the study area for the period (1980-2016), are

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determined as following: the total rainfall is (418 mm), the average of relative humidity (29.96%), the average of temperature (15.81 C°), wind speed average (1.94 m/sec), sun shine duration average (8.28 h/day), and the total of the evaporation (1674.8 mm), the results are listed in Table 1. Varies relationships are correlated between the climatic variables, where, Relative humidity is correlated inversely with temperature, evaporation and wind speed; and normally with rainfall as shown in Figure 3.

I. Evapotranspiration

The potential evapotranspiration is a combined term of evaporation and transpiration is defined as the total loss of water through evaporation and transpiration from the soil-plant system [6]. Thornthwiate suggested an equation to calculate the potential evapotranspiration after conducting several experiments on various semi-wet and semi-arid climate types depending on the temperature only [7, 1]. The evapotranspiration in the study area is calculated for each month as follows:

PEx=16[10tn/J] ^{a} (1)

$J = \sum_{j=1}^{12} j$ For the 12 month (2)

j= [tn/5]1.514 (3)

a = (675 ×10-9) J3 - (771×10-7) J2 + (179×10-4) J + 0.492 ………... (4)

a =0.016 J+0.5

The value of (a) equals (1.68).

Where:

PEx = Potential evapotranspiration for each month (mm / month).

t = Monthly mean air temperature (C°).

n = Number of monthly measurement.

J = Annual heat index (C°).

j = Monthly temperature parameter (C°).

a = Constant.

The values of potential evapotranspiration for each month are determined in Table (2). The correlation graph of each of the potential evapotranspiration PE, and correct evapotranspiration PEc are explained in Figure 4.

II. Water Surplus (WS) and Water Deficit (WD)

Water surplus is defined as the excess of rainfall values over the corrected evapotranspiration values during specific months of the year, while water deficit is the excess of corrected evapotranspiration values over rainfall values during the remaining months of that year. The actual potential evapotranspiration (APE) could be derived as follows [1]:

WS = P – PEc (5)

PEc = APE, when P > PEc (6)

WD = PEc – P (7)

P = APE, when P < PEc (8)

Where:

WS: Water surplus (mm).

WD: Water deficit (mm).

APE: Actual Evapotranspiration (mm).

PEc: Correct potential evapotranspiration.

P: Rainfall

In the first case (water surplus period), If the soil moisture is equal to zero, the water surplus and water deficit are calculated without using it. Monthly averages of APE, WS and WD, all are shown in Table (3). The water surplus amount is (330.98 mm) from annual average rainfall (418 mm) and it is restricted between November and April because rainfall amounts exceed PEc, hence; values of rainfall are greater than correct evapotranspiration, therefore the actual evapotranspiration (APE) equals the correct evapotranspiration. The water surplus represents the surface runoff plus the groundwater recharge after the soil is fully saturated [6]. The soil moisture is consumed either by evaporation from the soil or by the plant. Therefore it is considered as a part of the water losses as that of potential evapotranspiration [2].

In the second case (water deficit period) water deficit percentage equals (20.82 %) from annual average rainfall, correct evapotranspiration is greater than rainfall; where the actual evapotranspiration is equal the rainfall. The monthly averages of APE, WS and WD are shown in Table (3).

The total annual value of water surplus is (330.98 mm) from total rainfall and it is restricted between November and April because rainfall exceeds PEc. (Where the soil moisture considered =0), the water surplus ratio from the yearly rainfall can be represented as follows:

WS % = WS/P ×100

WS% = 330.98 /418×100 = 79.18%

WD% = 100 – WS%

WD% = 100 – 79.18 % = 20.82 %

Figure (5) shows the relationship between the monthly means of rainfall and corrected evapotranspiration, which shows the water surplus and water deficit periods.

III. Groundwater Recharge

Groundwater recharge depends on the amount of annual rainfall falling and the space area studied. Rainfall average rate for the period (1980-2016) was (418) mm, the water surplus was calculated (330.98) mm. The surface runoff accounted and used the following formula [8] to calculate the annual amount of water that recharges the groundwater.

$R_s = (P-178)\ P/2540$ (9)
$= (418-178)\ 418/2540$
$= 39.36$ mm
$R_e = 0.87\ (P-50)$ (10)
Where:
R_s: Surface runoff (mm)
R_e: Recharge (mm)
P: Total Monthly rainfall (mm)
The application of the preceding formula is to calculate the monthly recharge of climate information obtained from the Erbil meteorological station and the results are shown in Table (4).
$R_e = 87.82 / 418 \times 100 = 21.01\%$
From the application of water balance calculations depending on monthly averages of rainfall and potential evapotranspiration for the period (1980 - 2016) we notes that the total annual rainfall reached (418 mm) is achieved from a water surplus (330.98) mm divided into surface runoff value of (39.36) mm and rate of annual rainfall (9.41%) and groundwater recharge (87.82) mm and the percentage of annual rainfall (21.01%). Overall, the proportion of water surplus rate of the annual rainfall was (79.18%) offset by (20.82%) total water loss by actual evapotranspiration.
Also, the annual recharge rate for the central Erbil Basin is calculated as follows:
$\text{Annual Recharge} = 1400 \times 10^6 \times 87.82 \times 10^{-3}$
$= 122.94 \times 10^6\ m^3/year$

Classification of Climate

There are many classifications for climate complied and proposed by many scientists and researchers to find and determine the type ofclimate [9]. Two of these classifications will be used to delineate the type of climate in the study area as follows:
[10] suggested a classification depending on humidity index (H.I) which represents the ratio between the rainfalls to correct potential Evapotranspiration, as shown in the Table(5).
H.I. = P/PEc (11)
Where:
H.I: Humidity index.
P: rainfall (mm).
PEc: Corrected potential evapotranspiration (mm).
The classification suggested by [11] for determining the climate type by using the annual dryness treatment depends on the amount of rainfall and temperature, according to the following equations:

$AI - 1 = (1.0 \times P) / (11.525 \times t)$ (12)
(t should not equal zero)
$AI - 2 = 2\sqrt{p} / t$ (13)
Where:
AI: Aridity index
P: Annual rainfall (mm)
t: Temperature (C°).
The value of (AI-1) represents the classification of the dominated climate, while the value of (AI-2) represents a modification of the latter classification as shown in Table (6). The values of AI-1 and AI-2 becomes as follows:
$AI\text{-}1 = (1.0 * 418) / (11.525 * 15.81) = 2.3$
$AI\text{-}2 = 2\sqrt{P} / t = 2 * \sqrt{418} / 15.81 = 2.586$
When comparing the values of (AI-1) and (AI-2) with the type of climate reveals that the dominated climate in the area is Moist – Humid to Moist.

4. Conclusion

1. This study showed that there is a water surplus of (79.18%) of the total rainfall (418 mm) based on the water balance.
2. The water surplus is divided into surface runoff (39.36 mm) with a rate of (9.41%) and groundwater recharge of (87.82 mm) with a rate of (21.01%) of the total rainfall. The water deficit represents (674.21mm) of the corrected potential evapotranspiration.
3. The climate of the study area is diversity between the wet climates in winter to the dry climate in summer and in most cases, it can be considered that the climate of the study area is Humid to moist.

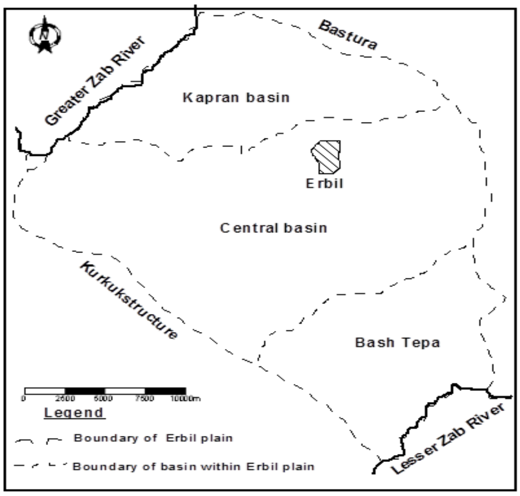

Figure1: Hydrogeological Basin to Erbil Plain after [1]

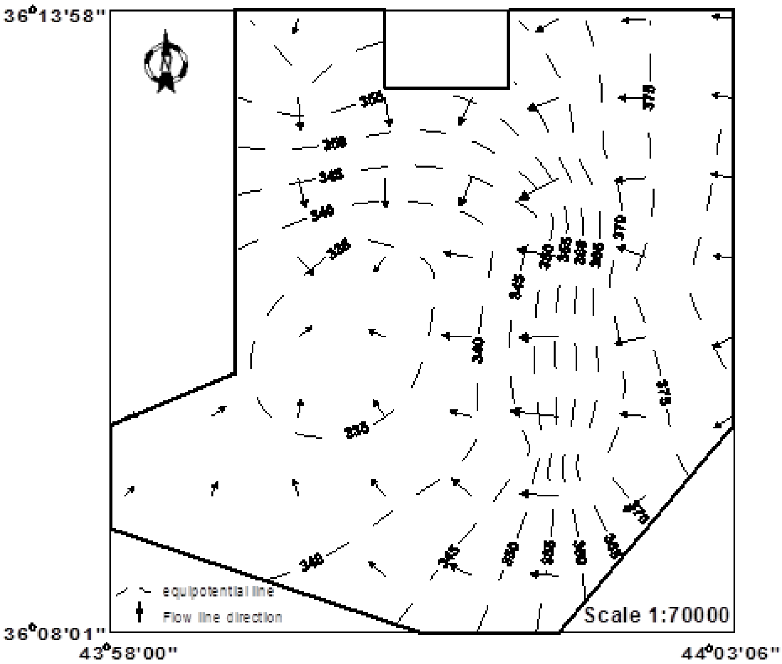

Figure2: levels and movement of groundwater in the study area after [3].

Table (1): Monthly averages records of climatic parameters in Erbil station for the period (1980-2016) [4]

Months	Average Monthly Rainfall (mm)	Average Monthly of Relative Humidity (R.H.) %	Mean Monthly Temperature (Cº)	Wind Speed (m/Sec)	Sun Shine (hours/day)	Mean Monthly Evaporation (mm)
Oct.	13.3	13.6	16.9	1.5	9	161.8
Nov.	43.93	20.4	11.8	1.8	5	109.7
Dec.	72.06	22.15	5.78	1.5	4.8	86.8
Jan.	76.24	49.6	6.3	1.5	4.8	89.2
Feb.	76.18	41.7	6.2	1.8	5	86.2
Mar.	76.48	42.18	9.48	2.3	5.5	87.6
Apr.	47.03	46.7	11.2	2.1	8	96.5
May.	13.03	44.9	11.3	2.1	9.5	110.2
Jun.	0.0	31.4	28.3	2	12	188
Jul.	0.0	21.6	28.9	2.7	12.8	217
Aug.	0.0	13.4	27.4	2	12	230.7
Sep.	0.0	11.9	26.2	2	11	211.8
Total	418	359.53	-	-	-	1674.8
Monthly Mean	34.85	29.96	15.81	1.94	8.28	139.56

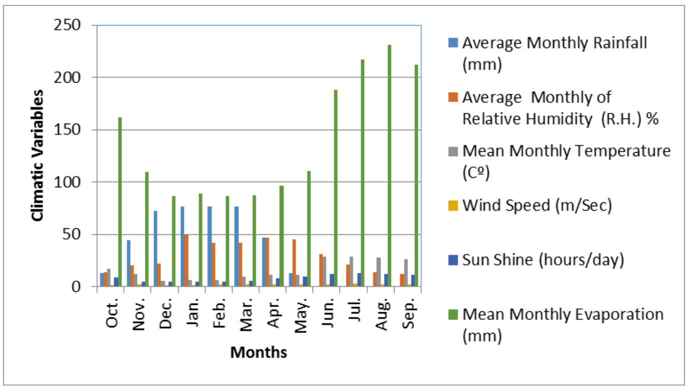

Figure 3: Monthly rainfall, relative humidity, temperature, wind speed, sunshine and evaporation from Pan Class (A) in the study area for the period (1980-2016) taken from the Erbil Meteorological station

Table 2: Potential evapotranspiration (PEx) mm for Erbil by Thornthwiate method (1948) [6]

Months	a=1.68 t c°	t/5	$J=(t/5)^{1.514}$	$(10t/J)^a$	PE_x (mm)	DT/360	PE_c (mm)
Oct.	16.9	3.38	6.32	4.01	64.16	0.775	49.4
Nov.	11.8	2.36	3.67	2.2	35.2	0.41	14.43
Dec.	5.78	1.156	1.24	0.66	10.56	0.41	4.33
Jan.	6.3	1.26	1.42	0.76	12.16	0.41	4.98
Feb.	6.2	1.24	1.38	0.74	11.84	0.388	4.73
Mar.	9.48	1.9	2.64	1.51	24.16	0.47	11.35
Apr.	11.2	2.24	3.4	2.01	32.16	0.66	21.22
May.	11.3	2.26	3.43	2.04	32.64	0.81	26.43
Jun.	28.3	5.66	13.8	9.53	152.48	1.0	152.48
Jul.	28.9	5.78	14.24	9.87	157.92	1.1	173.71
Aug.	27.4	5.48	13.13	9.03	144.48	1.03	148.32
Total			J= 73.94				734.58

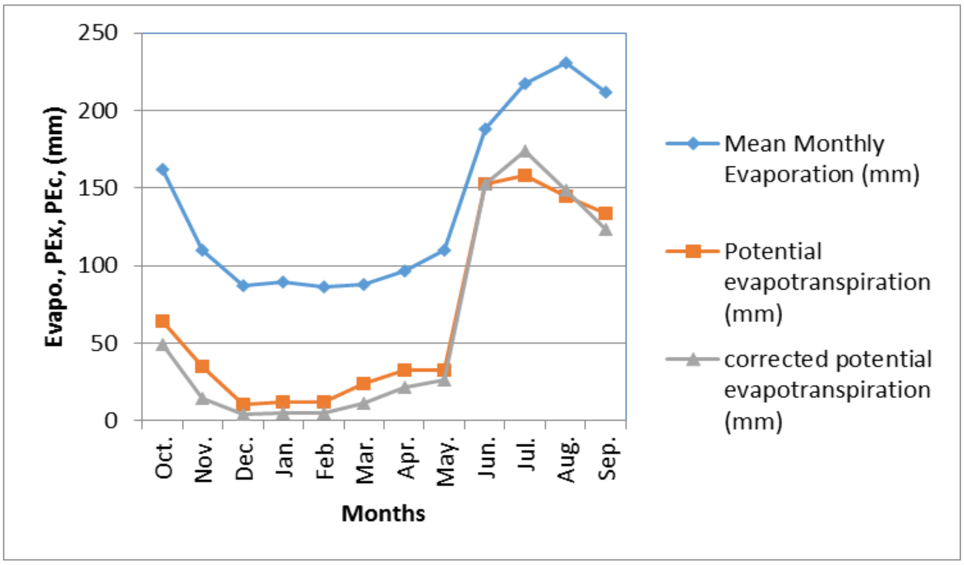

Figure 4: Evaporation, PEx and PEc correlation graph in Erbil meteorological station for the period (1980-2016).

Table 3: The values of water surplus and water deficit for the study area in mm

Months	P(MM)	PE_c (mm)	APE (mm)	W_s (mm)	W_D (mm)
Oct.	13.3	49.4	13.3	0.0	36.1
Nov.	43.93	14.43	14.43	29.5	0.0
Des.	72.06	4.33	4.33	67.73	0.0
Jan.	76.24	4.98	4.98	71.26	0.0
Feb.	76.18	4.73	4.73	71.45	0.0
Mar.	76.48	11.35	11.35	65.13	0.0
Apr.	47.03	21.22	21.22	25.81	0.0
May.	13.03	26.43	13.03	0.0	13.4
Jun.	0.0	152.48	0.0	0.0	152.48
July.	0.0	173.71	0.0	0.0	173.71
Aug.	0.0	148.32	0.0	0.0	148.32
Sep.	0.0	123.2	0.0	0.0	123.2
Total	418		87.37	330.98	647.21

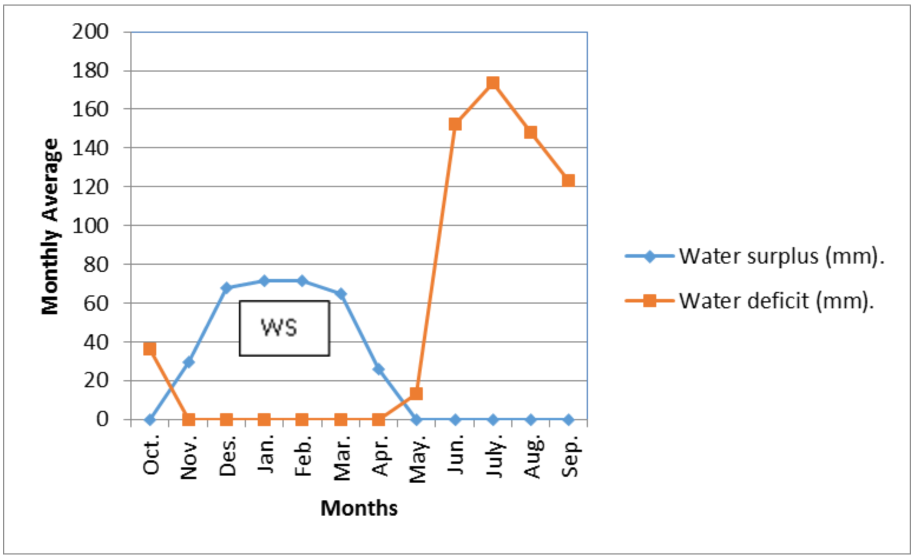

Figure 5: The relationship between water surplus (WS) and the water deficit (WD) for the study area.

Table 4: Monthly Recharge in the study area for the period (1980-2016)

Months	Monthly P. (mm)	R_e (mm)
Oct.	13.3	0.0
Nov.	43.93	0.0
Des.	72.06	19.2
Jan.	76.24	22.82
Feb.	76.18	22.77
Mar.	76.48	23.03
Apr.	47.03	0.0
May.	13.03	0.0
Jun.	0.0	0.0
Jul.	0.0	0.0
Aug.	0.0	0.0
Sep.	0.0	0.0
Total (mm)	418	87.82

Table 5: Evaluation of monthly climate averages in the study area after [10].

Months	P. (mm)	PE_c (mm)	H.I.	Kettaneh and Gangopadhyaya, 1974
Oct.	13.3	49.4	0.27	Moderate to dry
Nov.	43.93	14.43	3.04	Humid
Dec.	72.06	4.33	16.64	Humid
Jan.	76.24	4.98	15.31	Humid
Feb.	76.18	4.73	16.1	Humid
Mar.	76.48	11.35	6.73	Humid
Apr.	47.03	21.22	2.21	Humid
May.	13.03	26.43	0.493	Moist
Jun.	0.0	152.48	0.0	Very dry
Jul.	0.0	173.71	0.0	Very dry
Aug.	0.0	148.32	0.0	Very dry
Sep.	0.0	123.2	0.0	Very dry

Table 6: Climate classification depending on values of annual dryness treatment (A-I.1 and A-I.2) after [11]

Type. 1	Evaluation	Type. 2	Evaluation
AI-1>1.0	Humid to moist	AI-2>4.5	Humid
		2.5<AI-2<4.0	Humid to moist
		1.85<AI-2<2.5	Moist
		1.5<AI-2<1.5	Moist to sub-arid
AI-1<1.0	Sub arid to arid	1.0≤AI-2<1.5	Sub arid
		AI-2<1.0	Arid

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