P- ISSN 1991-8941 E-ISSN 2706-6703 Journal of University of Anbar for Pure Science (JUAPS) Open Access
2017,11 (3) :110-115

Meteorological Water Balance of Khan Al-Baghdadi and surrounding area within Anbar Governorate – West of Iraq.

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A R T I C L E I N F O

Received: 28 / 12 /2017
Accepted: / /
Available online: 22/6/2018
DOI: 10.37652/juaps.2017.145556
Keywords:
Water Balance,
Thornthwaite method,
West of Iraq.

A B S T R A C T

The water balance equation for any natural area or water body indicates the relative values of inflow, outflow and change in water storage for the area or water body. Analysis of watersheds and drainage patterns of the studied area plays a vital role in understanding the hydrogeological behavior and expressing the prevailing climate, geomorphology and structural antecedents of terrains. This research will study the climate characteristics and meteorological water balance to calculate runoff and groundwater recharge as water surplus. The research used the meteorological parameters recorded in Hit station during the period (1995-2010) to describe climate conditions as well as calculating water surplus using Thorntwaite formula. The climate of area classified as hot dry in summer and cold low rainfall in winter as a continental semi-dry to dry climate class. The calculated potential evapotranspiration was (1174.3) mm, while calculated actual evapotranspiration was (69.59) mm. The amount of water surplus was (31.71) mm, divided into (20.26) mm as runoff and (11.45) mm as groundwater recharge. The average annual of groundwater recharge in the area was (72,020,500) cubic meters. The estimated percent of the water surplus and deficit from the annual rainfall was (31.3%) and (68.69%) respectively.

Introduction

The study of the water balance is the application in hydrology of the principle of conservation of mass, often referred to as the continuity equation. This states that, for any arbitrary volume and during any period of time, the difference between total input and output will be balanced by the change of water storage [1].

The water balance structure of lakes, river basins, and ground-water basins forms a basis for the hydrological substantiation of projects for the rational use, control and redistribution of water resources in time and space. Knowledge of the water balance assists the prediction of the consequences of artificial changes in the regime of streams, lakes, and groundwater basins [2]. Due to increased variability of water supply in agriculture in the last decade, it is necessary to analyze both extremes: water deficit and water surplus. Water balance simulation models are numerous and diverse. They can be classified into two groups: the first is mechanistic models based on the physical equations governing soil water diffusion, on the other hand, simpler and more empirical models, generally called agro-meteorological models deals with standard meteorological data. The second type is based on budget techniques and requires a few input data, which are easily obtainable from meteorological networks [3].

The study area which is located in the northwest of Anbar Governorate (west of Iraq), covers an area of (6290) km^2 within (41° 50'- 42 ° 45') E and (33 ° 30 ' - 34 ° 15') N, figure (1).

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In general, several previous studies have been done within western desert area as mentioned below:

1- Transboundary aquifers between Iraq and neighboring countries [4].

2- Hydrogeology of groundwater aquifers in the Western Desert - west and southwest of the Euphrates River [5].

3 - Assessment of groundwater resources in Iraq and management of their use [6].

4- Hydrogeological study of Khan Al-Baghdadi area in Anbar governorate - West of Iraq [7].

This research will study the meteorological water balance in order to calculate the water surplus and water deficit, where the classical method of water balance calculations considers precipitation on the input side and runoff, evaporation and infiltration on the output one. It aims at the best estimate possible of the water balance components with the simplest formulation and the minimum set of input data.

Geological Setting and Startigraphy:

The area is built up of sedimentary rocks ranging in age from lower Oligocene to Pliocene, with different types of Quaternary deposits (Pleistocene-Holocene). The area lies within different structural zones from east to west, The Tigris subzone up the Mesopotamian zone of the Unstable Shelf and the Salman and Rutba-Jazira zones of the Stable Shelf. The area lies partly within the Stable Shelf represented by two zones (Al-Rutbah and Al-Jazira-Salman zones), and partly within the Unstable Shelf, represented by Mesopotamia zone (Tigris Subzone). Another important structural feature, is Abu-Jeer fault zone which is also sub surface fault, running N-S. The indications of this fault on the surface are well expressed by numerous springs (in Hit, Kubaisa and Abu-Jeer vicinities) which yield mineralized water and bitumen seepages [8].

- Anah Formation (Lower Oligocene): Consists of massive, coralline, creamy, very hard limestone and dolomite limestone, which are locally strongly Karstified leading to cavities and caverns of different sizes.
- Euphrates Formation (Lower Miocene): It consists of thin basal conglomerate or basal clastic with recrystallizedy cherty, silicified, ferruginous and marly limestone, and greenish marl.
- Fatha (Lower Fars) Formation (Middle Miocene): Its normal lithological constituents of cyclic nature (marl, limestone , gypsum and claystone).
- Quaternary deposits consist of:
- River terrace (Pleistocene): Composed of medium grained, well rounded pebbles
- Gypcrete (Pleistocene-Holocene): Composed of secondary gypsum or highly gypiferous soil.
- Slope deposits (Pleistocene -Holocene): Composed of sand, silt and clay with rock fragments.
- Residual Soil (Pleistocene-Holocene): Consists of sandy, silty clayey, brown soil with limestone fragments.
- Valley fill deposits (Holocene): Consist of gravels mixed with sand and high admixture of rock fragments [9].

Materials:

1- Topographic maps scale of 1:250000.
2- Meteorological parameters of Hit meteorological station during the period (1995-2010), [10].
3- Runoff coefficient method.
4- Grapher software version (1.09) demonstrating graphs.

Theory:

Water balance techniques are a solution of important theoretical and practical hydrological problems [11]. Depending on water balance approach, it is possible to make a quantitative evaluation of water resources and their change under the influence of man's activities. An understanding of the water balance is also extremely important for studies of the hydrological cycle where the relationship between rainfalls on an area with the total loss of water in different forms can be distinguished. The water balance equation can be expressed as follows [12]:

Input – Output = Change in Storage

Rainfall is the only input element in the water balance, where set of outputs as evaporation, transpiration and consumption. Evaporation reflects the loss of water from water surfaces or soil, while transpiration and consumption are a process of water evaporation from plants, these two processes are called Evapo-transpiration or potential Evapotranspiration which reflected the water losses with abundant quantity of water exist in the basin area and it can be calculated by specific equations, while actual Evapotranspiration can be determined when quantity of water is limited [13]. The second element of the water balance is soil moisture content, which depends on soil type, texture and depth. This element affects surface runoff and groundwater recharge, which represent the last elements of the water balance. Surface runoff or groundwater recharge is achieved only when soil is saturated [13]. The filtration rate decreases gradually within the time of rainwater filtration to the soil zones and surface run off can be occurred at any time when rain intensity is higher than the filtration rate (before the soil moisture content is completed and reached its final level) [12]. The potential evapotranspiration can be calculated by experimental equations as Thornthwaite equation [14]. This variable is often with high values and greater than the rainfall quantity (if exist) at the time when temperatures is high, which generates a water deficit in the basin and at the same time, this variable values fall to the lowest level in a period of low temperatures accompanied by increasing rate of rainfall which generates a water surplus. Most hydrological science researchers supposed that potential evaportranspiration is equal to actual evapotranspiration when rainfall is greater than potential evapotranspiration. Thus, the water surplus can be divided into run off and natural groundwater recharge after soil moisture saturation is complete [12, 15]

P > PE ----- PE = Eta --------- (1)

WS = P – Eta --------- (2)

And WS = Ro + Re + SM --------- (3)

P: Rainfall, PE: potential evapotranspiration, Eta: actual evapotranspiration, WS: water surplus, Ro: surface runoff, Re: groundwater recharge, SM: soil moisture.

Whenever the sum of total soil moisture content and rainfall is higher than potential evapotranspiration, then rainfall will be greater than potential evapotranspiration, and when soil moisture or rainfall or both begins gradual and naturally decrease in this period below potential evapotranspiration values, then the actual evapotranspiration will be equal to water amount exist in the basin as a soil moisture storage or rainfall. Finally, whenever rainfall and soil moisture content are absent, the actual evapotranspiration will be zero because there is no water can evaporate or be transpires by the plant [15].

P < PE -------- WS = 0

If P + SM > PE

Then PE = Eta

If P + SM < PE

Then P + SM = Eta

WD = PE - (P+ SM) -------- (4)

W.D.: Water Deficit.

It seems from above equations that soil moisture in the first period (P> PE) will be an acquired component in the water balance, where a quantity of rainwater is exploited before generation of surface runoff and groundwater recharge. In the second period (P <PE) it seems that soil moisture is a missing component in the water balance for its contribution with the precipitation in actual Evapotranspiration.

Results and Discussion:

Climate: Depending on Hit meteorological station records and its monthly parameters during (1995-2010) mentioned in table (1) and plotted figure (2), the climate is classified according to Doornbos and Pruitte; 1977 (table 2) [16] as continental semi-dry to dry climate with average annual rainfall (101.3) mm, evaporation exceed (2500) mm., light wind speed exceed (1.76) m/sec., with general increasing of sunshine hours above (11) hours /day. The annual wet period in the area extends between October to May characterized by monthly variation of rainfall while dry period extends from June to September.

Water Balance Calculation:

The Thornthwaite water balance [14] used as account procedure to analyze the allocation of water among various components of the hydrologic system. Inputs data in model are monthly temperature and precipitation. Outputs include monthly potential and actual evapotranspiration, soil moisture storage, snow storage, surplus, and runoff. Potential Evapotranspiration was calculated by applying Wilson,1984 [17] formula:

$$PE = 16\left[\frac{10tn}{J}\right]^{a} \quad \text{-------- (5)}$$

$$J = \sum_{1}^{12} j \quad \text{---------(6)}$$

$$j = \left[\frac{tn}{5}\right]^{1.514} \quad \text{---------(7)}$$

$$a = 0.016J + 0.5 \quad \text{------- (8)}$$

PE: potential evapotranspiration, J: Heat Index, j: Coefficient monthly temperature (°C), a: Constant, tn: Average monthly temperature (° C).

Depend on the climatic data shown in table (1), and using Thornthwaite equation, the actual and potential evapotranspiration where calculated and the results shown in table (3). Based on the geological sequence in the Khan al-Baghdadi area and the nature of Quaternary deposits, the slope deposits and valley fill deposits are the only sediments containing silt and mud which extending along seasonal valleys in the area. These deposits have relatively small exposure and containing rock fragments of limestone and gypsum of not more than one meter thick. Thus, it can assume that soil moisture is not effective in water balance equation [18]. The generated water surplus moves quickly towards runoff or infiltrating into groundwater horizon within fractures and joints in limestone and dolomite geological formation represented by mainly by Euphrates and Fatha [7]. The water surplus in the basin was (31.71) mm divided into natural recharge of groundwater, and surface runoff in seasonal valleys.

Runoff coefficient method [19] was used to calculate runoff by applying formula:

$$Q = KP \qquad \text{---------} \ (9)$$

Where, Q: Runoff, P: Precipitation and K: a constant having a value less than (1) or at most equal to (1). The value of K depends upon the imperviousness of the drainage area. Its value increases with the increase in, imperviousness of the catchments area, and may approach unity (1.0) as the area becomes fully impervious. The value of K depending on roof type where it was selected as a soil surface in the area represented by residual soil of Quaternary deposits with low rate of infiltration, K value was (0.2) from above mentioned data. Calculations indicate that runoff was (20.26) mm, while the percentage of runoff from the annual precipitation is equal to (20%) discharged into seasonal valleys towards Euphrates river. (11.45) mm represents the natural groundwater recharge, with (11.3%) percent of annual rainfall. The average annual of groundwater recharge in Khan Al-Baghdadi area was (72,020,500) cubic meters. Finally, the percentage of the water surplus and deficit estimated from the annual rainfall are (31.3%) and (68.69%) respectively.

Conclusions:

1- The climatic factors are used to describe the climate characterization and water balance calculation in any basin depends on the meteorological stations which provide data as precipitation, temperature, evaporation, humidity, wind, cloudiness, and radiation. The climate of Khan Al-Baghdadi area classified as hot dry in summer and cold low rainfall in winter as a continental semi-dry to dry climate class.

2- The average annual rainfall in the area was (101.3) mm, with evaporation exceed (2500) mm., light wind speed exceed (1.76) m/sec., and sunshine hours above (11) hours /day.

3- Depending on climate data (temperature, precipitation and evaporation) and using Thornthwaite methods, the calculated potential evapotranspiration was (1174.3) mm. while calculated actual evapotranspiration was (69.59) mm. The water surplus was (31.71) mm, while the amount of runoff and groundwater recharge are (20.26), (11.45) respectively.

4- The runoff and groundwater percentage from annual precipitation is equal to (20%), (11.3%) respectively.

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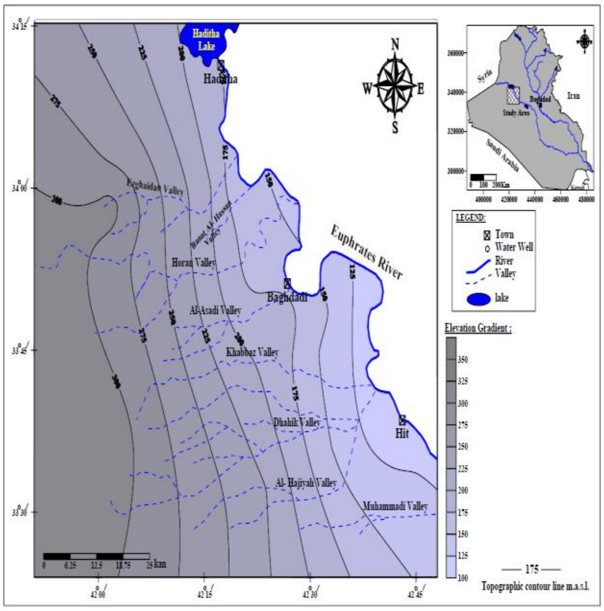

Figure (1): Topographic Map of Khan Al-Baghdadi Area.

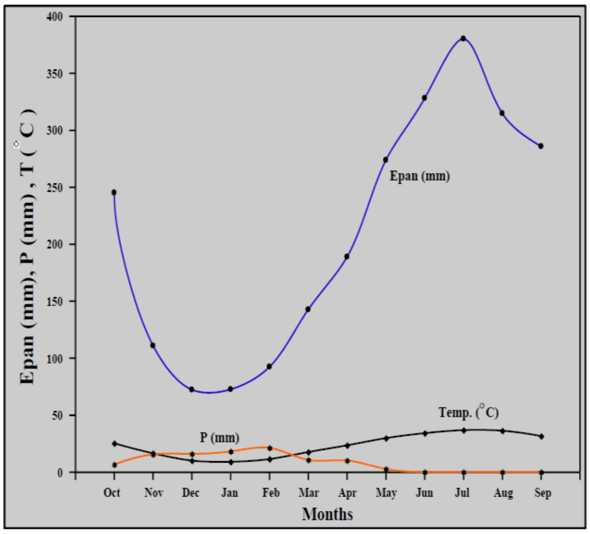

Figure (2): Monthly Meteorological Parameters distribution of Hit Station during (1995-2010).

Table (1): Monthly average of meteorological parameters of Hit station during (1995-2008)

Month	P (mm)	T ° C	Epan (mm)	Month	P (mm)	T ° C	Epan (mm)
Oct.	6.6	25.3	245.3	Apr.	10.2	23.5	188.9
Nov.	15.6	16.5	110.9	May	2.7	29.8	273.9
Dec.	16.0	10.1	72.3	June	0.0	34.2	328.2
Jan.	18.2	9.0	72.6	July	0.0	36.9	380.3
Feb.	21.3	11.5	92.4	Aug.	0.0	36.3	314.9
Mar.	10.7	17.6	142.7	Sep.	0.0	31.6	285.9
Sum	101.3						2508.3
Avg.		23.52					

Table (2): Classification of climate according to (Doornbos and Pruitte; 1977) (15)

Epan mm	Tº C	R.H. %	Sun Shine h.	Climate
> 250	> 30	< 20	> 19.2	Dry
250-200	-	20-50	19.2-14.4	Semi Humid
< 200	< 20	> 50	< 14.4	Humid

Table (3): Water balance calculation depending on average monthly parameters of Hit station (1995-2010)

Month	P (mm)	T ° C	PE (mm)	ETa (mm)	WS (mm)	WD (mm)
October	6.6	25.3	85.85	6.6	0.0	79.25
November	15.6	16.5	27.71	15.6	0.0	12.11
December	16.0	10.1	7.55	7.55	8.45	0.0
January	18.2	9.0	5.57	5.57	12.63	0.0
February	21.3	11.5	10.67	10.67	10.63	0.0
March	10.7	17.6	32.68	10.7	0.0	22.16
April	10.2	23.5	70.67	10.2	0.0	60.47
May	2.7	29.8	132.37	2.7	0.0	129.67
June	0.0	34.2	190.43	0.0	0.0	190.43
July	0.0	36.9	232.90	0.0	0.0	232.9
August	0.0	36.3	223.21	0.0	0.0	223.21
September	0.0	31.6	154.51	0.0	0.0	154.51
Sum	101.3	23.52	1174.30	69.59	31.71	1104.71

الموازنة المائية المناخية لمنطقة خان البغدادي والمناطق المحيطة بها ضمن محافظة الانبار-غرب العراق

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الخلاصة :

إن معادلة التوازن المائي لاي منطقة او جسم مائي تشير إلى القيم النسبية للمدخلات والمخرجات والتغير في خزن المياه ضمن المنطقة او الجسم المائي . ان لتحليل الاحواض المائية او شبكات التصريف ومنها منطقة خان البغدادي دورا حيويا في فهم السلوك الهيدروجيولوجي وخصائص المناخ السائد وجيومورفولوجيا المنطقة والوضع التركيبي . يشمل البحث دراسة الخصائص المناخية والموازنة المائية لحساب تحديد الزيادة المائية التي تحقق الجريان السطحي وتغذية خزانات المياه الجوفية . تم استخدام المعلومات المناخية لمحطة الارصاد الجوي في مدينة هيت خلال الفترة (1995-2010) في وصف الظروف المناخية وحساب الفائض المائي باستخدام طريقة ثورنثويت. وصنف المناخ في منطقة الدراسة على انه قاري جاف الى شبه جاف حار في الصيف وبارد قليل المطر في فصل الشتاء. بلغ مجموع التبخر - نتح الكامن بـ (1174.3) ملم وبلغ التبخر - نتح الفعلي (69.59) ملم فيما بلغت الزيادة المائية في المنطقة (31.71) ملم منها (20.26) ملم كجريان سطحي و (11.45) ملم كتغذية طبيعية لخزانات المياه الجوفية . بلغ معدل التغذية الطبيعية السنوية للمياه الجوفية في المنطقة بحدود (72.0205) مليون م^3 فيما كانت نسبة الفائض المائي من الأمطار السنوية (31.3٪) ، بينما بلغت نسبة العجز المائي (68.69٪) كتبخر - نتح حقيقي.