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Hydrogeologic and Water Balance of Koi Sanjaq Basin, Northern Iraq

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Abstract

Hydrogeological investigation and water budget calculation of Koi Sanjaq basin is carried out. This investigation includes the determination of the aquifer types extending through the study area and flow direction as well as aquifer hydraulic properties values. Three main unconfined aquifer types were distinguished , they are (Pilaspi), , (Bihassan-Muqdadiya and Fatha –Injana) Formations , where the flow map of the unconfined aquifers shows that the flow direction is from northern and northeastern parts towards the south and southeastern parts i.e. .Lesser Zab River. Analysis of pumping test data of 9 selected wells from unconfined aquifers show that T values range from 1.51m^2/day to 64.4 m^2/day revealing the great variations in the aquifer lithology, extend of fissures and fractures as well as the saturated thickness of the water bearing zones. Water balance calculations are achieved using meteorological data of three meteorological stations: Erbil, Koysanjaq and Dukan , where Mehtas model is used to calculate the water surplus values which found to be equal 203.9 mm/ year. Soil Conservation Service method (SCS) and curve number methods are adopted to determine the amount of runoff where the soil type is the most critical factor. According to the infiltration rates measured by the authors, all of the study area soil is of A group, therefore the calculated value of runoff is 128.72mm/year. Overall calculations of the water balance components shows that the groundwater recharge is 75.18 mm/year, representing 10.84 % of the total rainfall for the study area.

Keywords: aquifer characteristic, flow net, water balance, Koi Sanjaq Basin

هيدروجيولوجية والموازنة المائية لحوض كويسنجق ، شمال العراق

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الخلاصة

تم اجراء دراسة هيدروجيولوجية وموازنة مائية لحوض كويسنجق حيث تضمنت تحديد طبيعه الخزانات المائية في الحوض ، اتجاه الجريان اضافة الى الخصائص الهيدروليكية للخزان الجوفي الاساسي . ميزت ثلاث خزانات رئيسة غير محصورة وهي بلاسبي ،باى حسن – مقدادية وفتحه –انجانة ، اذ بينت خارطة الجريان للخزان السطحي ان جريان المياه الجوفية هو من الاجزاء الشمالية والشمالية الشرقية باتجاه الاجزاء الجنوبية والجنوبية الغربية اي باتجاه نهر الزاب الاسفل. تراوحت قيم النقالية المحسوبة من معلومات الضخ التجربى لتسع ابار ضمن الخزانات غير المحصورة من 64.4 متر مربع باليوم الى 1.51 متر مربع باليوم موضحة التغيرات الكبيرة في صخارية الخزان ، امتداد التكسرات والتكهفات وتغاير السمك المشبع للطبقات المائية.تم استخدام المعلومات المناخيه لثلاث محطات هي اربيل، كويسنجق ودوكان لحساب الموازنة المائية بتطبيق نموذج مهتا لتحديد الفائض المائي الذي يساوي 203.9 ملم بالسنة اما طريقة ارقام المنحني

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فقد استخدمت لحساب مقدار السيح السطحي اعتمادا على نوعية التربة باعتبارها الاهم في هذا المجال. اوضحت قياسات معدلات الترشيح التي اجريت من قبل الباحثين ان كل ترب المنطقة هي من صنف A لذا فان قيم السيح السطحي المحسوبه كانت 128.72 ملم بالسنة . اوضحت الحسابات الاجمالية لعناصر الموازنة المائية ان مقدار تغذية المياه الجوفية كانت 75.18 ملم بالسنة وبنسبة 10.84% من الامطار الكلية في الحوض.

Introduction:

Koi Sanjaq City locates at about 75km to the east of Erbil governorate in the mountainous region, northeastern Iraq. It bounded by Sulaimaniya Governorate in the south east, Kirkuk on the south, Mosul on the west and Iraqi- Iranian borders from the north east. It has a coordinates of UTM (3967555 and 4001000) northing and (446000 and 496700) easting Figure- 1. The population of the whole Koisanjaq basin area is about (84569) persons Geographically the study area is undulated and contain hills and mountains in the north part , while in the south and south west the area is undulated contains hills only. The intensive farming of wheat and barley are distributed through Koisinjaq basin, depends mainly on rainfall. Tectonically the study area is located at boundary between high folded zone and foothill zone of chamchamal butma subzone [1] , the general structural feature trend of the area trending NW-SE as general trend of Zagras structure. Five geological formations are exposed; they range in age from middle Eocene to Pleistocene, with Quaternary deposits Figure- 2. The exposed formations are from older to younger:

1. Pila Spi Formation: This Formation is of Middle – Late Eocene [2]. It is composed mainly of light gray and yellowish white color, well bedded limestone and marly limestone. The thickness is 100-200 m, where the depositional environment is marine, lagoon.
2. Fatha Formation: This Formation is of Middle Miocene age [2]. It is composed of cyclic deposits of mudstone and thin layers of limestone and gypsum; The thickness is 100 - 200 m [3]. The depositional environment is marine and lagoon.
3. Injana Formation: This Formation is of upper Miocene age [2].It is composed of fine grained molasse sediments, which include sandstone, red or grey colored siltstone and claystone, The thickness is 150 – 200 m [3]. The depositional environment is continental, fluvio - lacustrine.
4. Muqdadiya Formation: This Formation is of Late Miocene – Pliocene in age, it composed of pebbly sandstone, siltstone and claystone; all are mainly grey in color. The thickness is 400 -1000 m [3] The depositional environment is continental, fluvio – lacustrine.
5. Bai Hassan Formation: This formation is Pliocene – Pleistocene in age [2]. It composed of thick conglomerate alternated with red claystone and grey sandstone. The thickness is 1000 – 2500 m [3]. The depositional environment is continental, fresh water molasses.
6. Quaternary Deposits: They cover several parts of the study area, especially the center of Koi Sanjaq city and some areas near the valleys [4]. Quaternary deposits are mainly of alluvial type and of Pleistocene – Holocene age, characterized by heterogeneous deposits and consist of alternation of gravel, sand, silt and clay.

Several studies have been carried out for this area, Stevanovic and Marcovic [5], studied the climate, hydrology, geomorphology and regional geology of the three northern governorates "Sulaimani, Erbil and Duhok", Bapeer [4] studied the infiltration rates and Atterberg Limits of soils in Koi Sanjaq City , Heedan & Bapeer [6] perform an evaluation of the water wells in Haibat sultan mountain, Koi Sanjaq area.

The main objective of this study is to determine the aquifer parameters and calculate the water balance components for the Koisanjaq basin

Hydrologic and Hydrogeologic Situation:

Lesser Zab River originating from Zagros Mountains of about 3000 m height in Iran and joins the Tigris River in Iraq, considered as a main source of surface water in the e study area. Also, ground water is other significant source for water, and some of villages in koi Sanjaq City are completely depend on the groundwater as a prime source of water in their supply systems [6]. The main distinguished hydrological units in the study area are:

1. Fissure karstic aquifer: It consists of limstone , dolomitic limestone and chalky limstone which considered as a very good aquifer in the study area, this aquifer represented by Pilaspi Formation.

2. Intergranular aquifer: This type of aquifer is good for groundwater accumulation, which consist of both unconsolidated materials and consolidated rocks, represented by Quaternary deposits, Bihassan and Muqdadiya formations Figure- 3.
3. Complex (intergranuler and fissured multi - layered aquifer**:** This aquifer represented by Fatha and Injana formations, it is characterized by low production, because it composed of very heterogeneous lithology (sandstone, siltstone, .marl, gypsum, and clay) [7]. Measurements of heads of 30 wells dispersed through the aquifers are used to construct the flow map. According to this map Figure- 4, the flow direction is from the north and northeastern parts towards the south and southeastern parts, i.e Lesser Zab River .

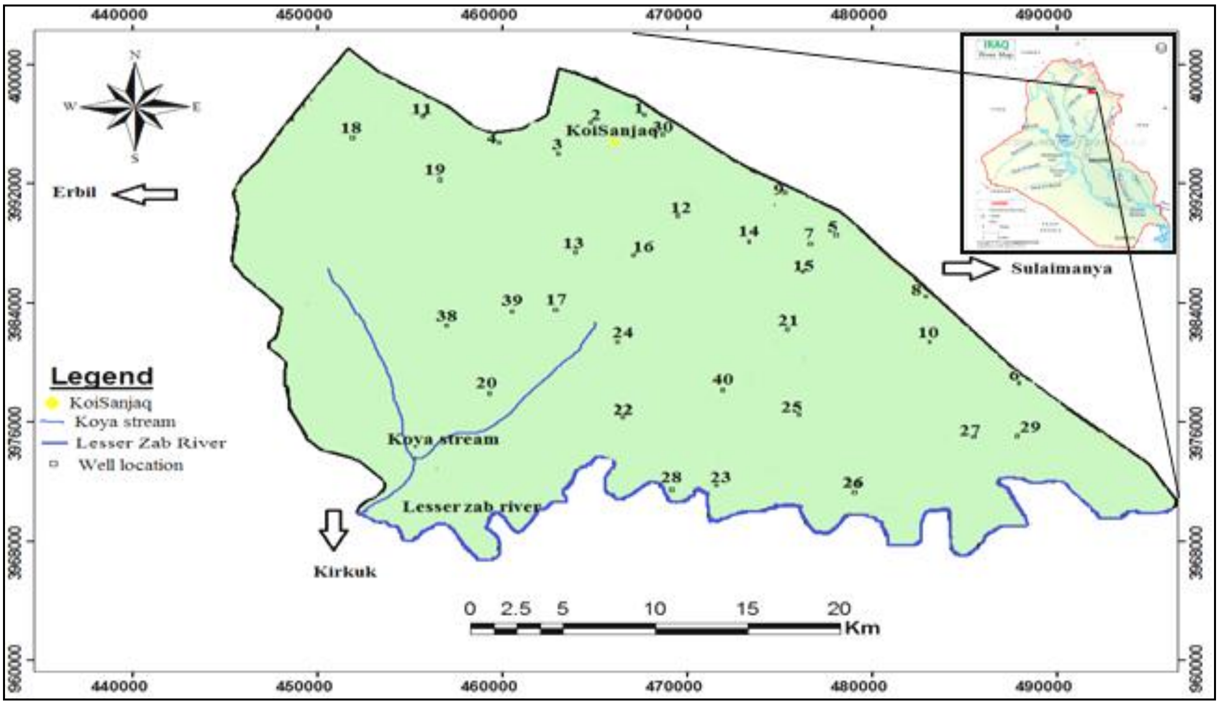

Figure 1- Location Map of the study area.

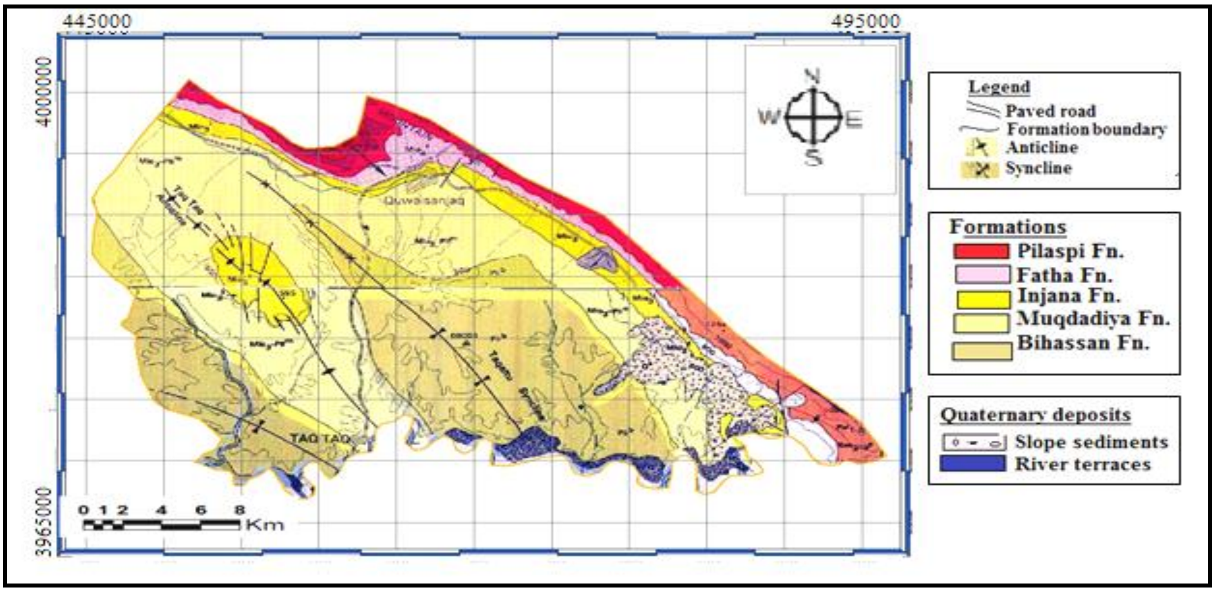

Figure 2- Geological map of the study area [8].

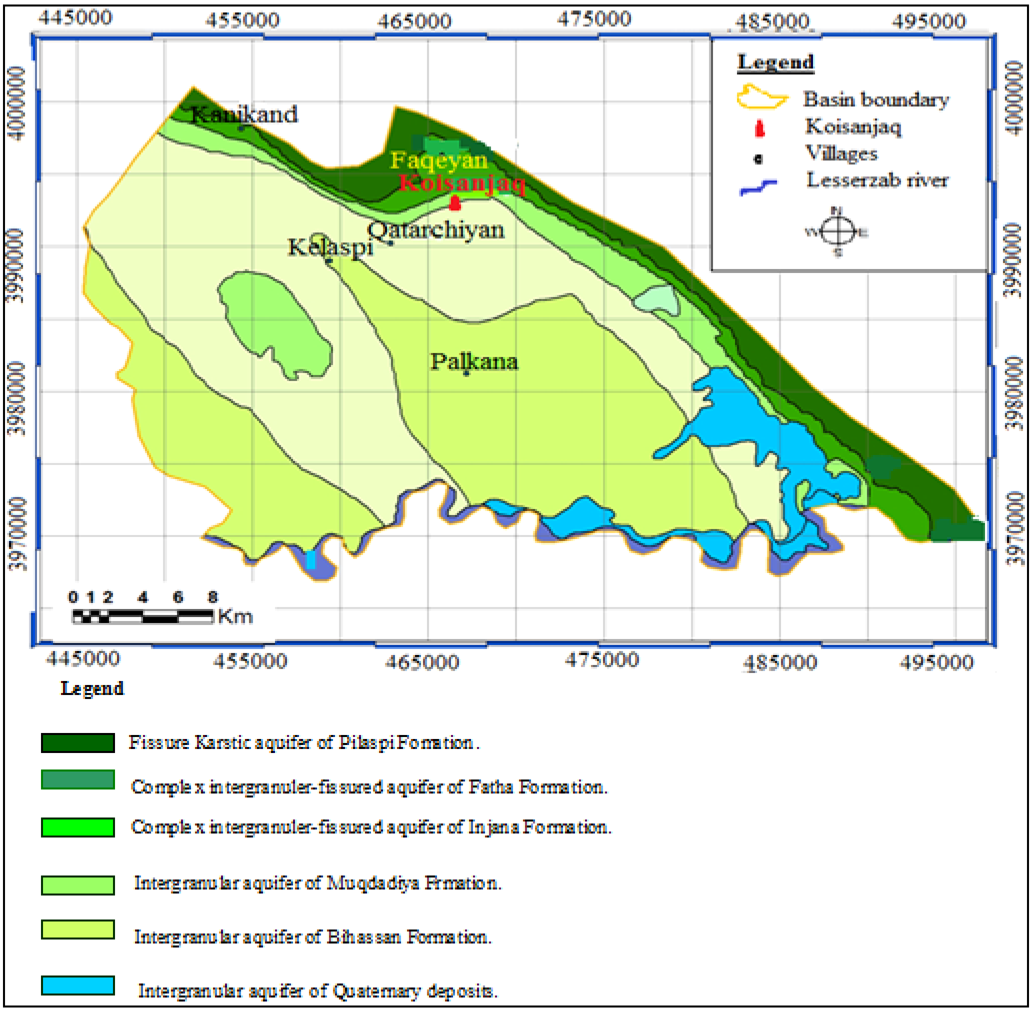

Figure 3- Hydrogeologic map of the study area.

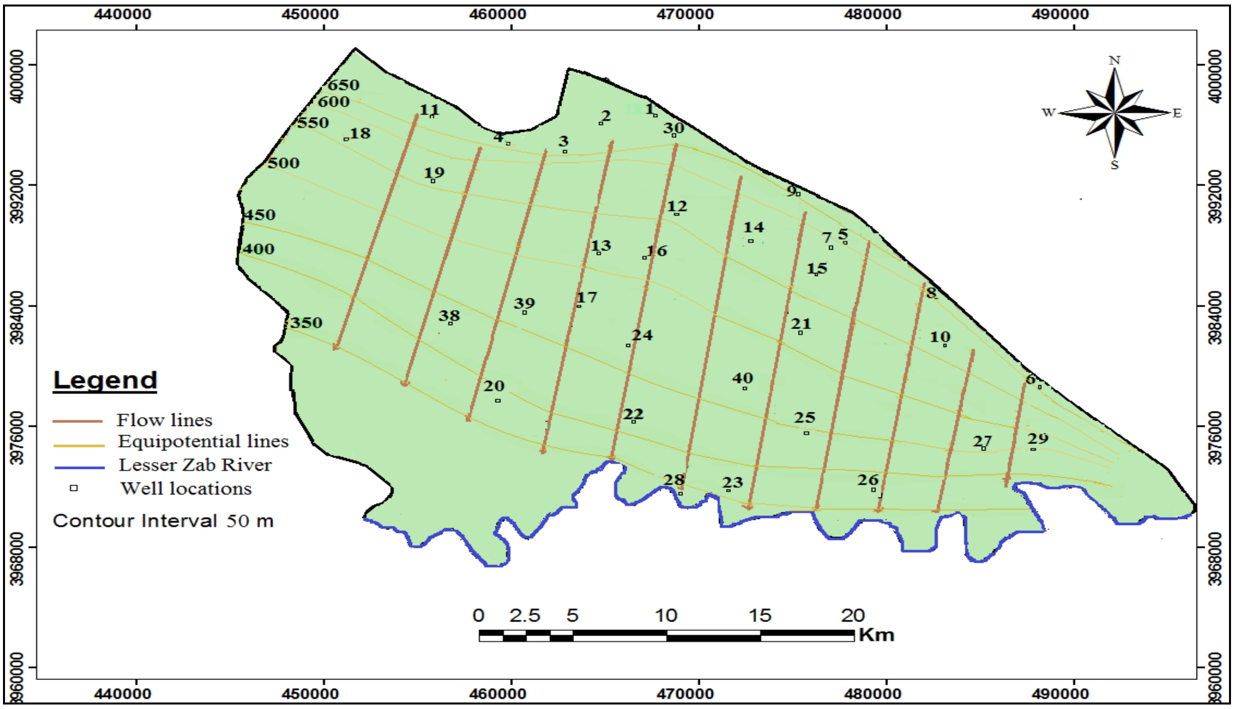

Figure 4- Groundwater flow map (meter above sea level) of the study area.

Material and methods

Aquifer hydraulic properties Transmissivity, hydraulic conductivity and specific capacity are calculated for 9 wells where Cooper Jacob method [9] is used for this purpose, using the following equation: Figure- 1, Tables- 1.

$$T = 2.3Q / 4\pi\Delta_S \quad (1)$$

T = Transmissivity (m^2/day) Q = well discharge (m^3/day).

Δ_S = Difference of drawdown per one log cycle (m).

$$\text{Hydraulic conductivity (K)} = T/D \quad (2)$$

D = aquifer thickness

The specific capacity of the selected wells is calculated by:

$$\text{Specific capacity (Sc)} = Q/S_w \quad (3)$$

Q = well discharge (m^3/day). S_w = total well Drawdown (m).

Precipitation, temperature, evaporation, relative humidity, wind speed and sunshine for Erbil, Koysanjaq and Dukan meteorological stations have been used to calculate the water balance components Table-2, where CROPWAT 8.0 program is used to determine the Evapotranspiration and effective rainfall values. This program is adopted by USDA (U.S. Department of Agriculture) where the calculation can be achieved as follows [10].

$$p_{eff} = T.R / 125 \times (125 - 0.2 \times T.R) \quad (4)$$

(T.R. < 250mm)

$p_{eff} = 125 + 0.1 \times T.R$ (T.R. < 250 mm)

Where; (T.R.) is total rainfall, p_{eff} = effective rainfall.

$$ET_o = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{(T+273)}U(es-ea)}{\Delta+\gamma(1+0.34U2)} \quad (5)$$

ETo= reference evapotranspiration	[mm day^{-1}]
Rn= net radiation at the crop surface	[MJ $m^{-2}day^{-1}$]
G= soil heat flux density	[MJ $m^{-2}day^{-1}$]
T= mean daily air temperature at 2 m height	[^oC]
U2= wind speed at 2 m height	[ms^{-1}]
es= saturation vapor pressure	[kPa]
ea= actual vapor pressure	[kPa]
es-ea= saturation vapor pressure deficit	[kPa]
Δ= slope vapor pressure curve	[kPa $^oC^{-1}$]
γ= psychrometric constant	[kPa $^oC^{-1}$]

Double ring infiltrometer method is used to measure the infiltration rates and calculate the infiltration capacity which in turn used to classify soil of the study area. Twenty four locations are selected , 16 locations from Bapeer [4] and anther locations within the research Figure-5, for conducting the infiltration depth measurements which taken at different time intervals i.e.1,2,3,4,5,8,18…….300min. The infiltration rate can be determined according to the following equation [11].

$$\text{Infiltration rate} = \frac{\text{Cumulative depth of infiltration}}{\text{Time (hour)}} \quad (6)$$

Statistical package for Social Science (SPSS) software program was used in estimating infiltration capacity rate using Horton's equation [12] as follows:

$$f(t) = f(c) + (fo - fc)\, e^{-kt} \quad (7)$$

Where:

f(t) = infiltration capacity (mm/hour)

f(c) = equilibrium infiltration capacity (mm/hour).

(fo) = initial infiltration capacity (mm/hour)

K= constant (1/hour).

t= total time during infiltration (hour).

Mehtas model is used to determine the water surplus [13], whereas the runoff value is determined by SCS (soil conservation service) method, Figure-6. The curve- number model was originally developed by the Natural Resources Conservation Service (NRCS), by U.S. Department of Agriculture [14] , it is the most widely method for estimating rain fall excess , by the following formula:

Q = Q = (P - 0.2S) 2 / (P - 0.2S) For P > 0.25S **(8)**

Where:

Q = runoff in (mm) of depth.

P = total precipitation (mm) (average monthly records used).

S = retention including the initial abstraction which is assumed to be 0.25S. Instead of specifying S directly, a curve number, CN, is usually specified, when CN related to S by:

CN = 1000 / (10 + 0.0394S) **(9)**

CN = curve number, Figure- 7.

Table 1- Data of the pumping wells

Well No.	Static Water level (m)	Q m^3/day	t_o min	Slope Δs/log cycle	Well Depth (m)	Aquifer thickness (m)	Type of Formation
1	62	280	0.055	0.8	216	154	Pilaspi
2	11	252	0.09	1.0	115	104	Pilaspi
5	83.26	402	0.28	1.2	148	64.74	Pilaspi
8	7.44	129.6	0.32	8	65	57.56	Fatha
9	4.31	108	0.45	9	55	50.69	Injana
16	8	86.4	0.12	10.5	65	57	Muqdadiya
20	1.71	120	0.18	9	53	51.29	Muqdadiya
23	10.98	259.2	0.05	5	90	79.02	Bihassan
25	25.02	123	0.03	5	75	49.98	Bihassan

Table 2- Mean monthly climatic parameters of the studied area for the period (1990 – 2013)

Months	Rainfall (mm)/year	Air temperature (°C)	Pan Evaporation (mm)	Relative humidity%	Wind speed (m/ sec)	Sunshine duration hour/day
January	145	7.3	51	67.6	2.3	4.1
February	116	7.6	52	68	2.4	4.6
March	112	12.3	96	59.6	2.7	7.6
April	75.6	18.3	118	55.6	2.6	7.4
May	18.3	25	205	41.6	2.6	8.6
June	1.4	30.9	313	33.3	2.7	9.9
July	0	34.8	358	30.3	2.5	10.9
August	0	34.5	322	29.3	2.5	10.2
September	0	29.4	188	38	2.2	9.8
October	25	23.2	151	40	2	7.3
November	80	14.25	80	60.3	1.8	5.5
December	120	9.8	57	65	2	4.5

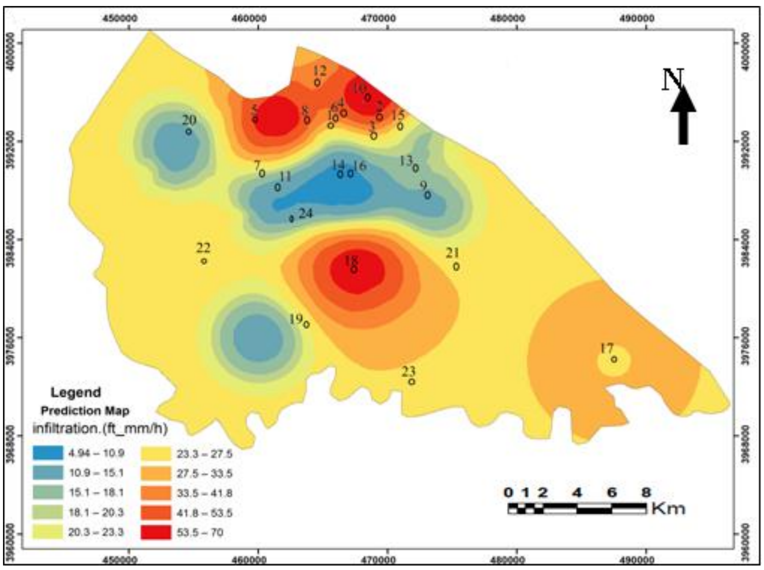

Figure 5- Infiltration rate of soil in the study area.

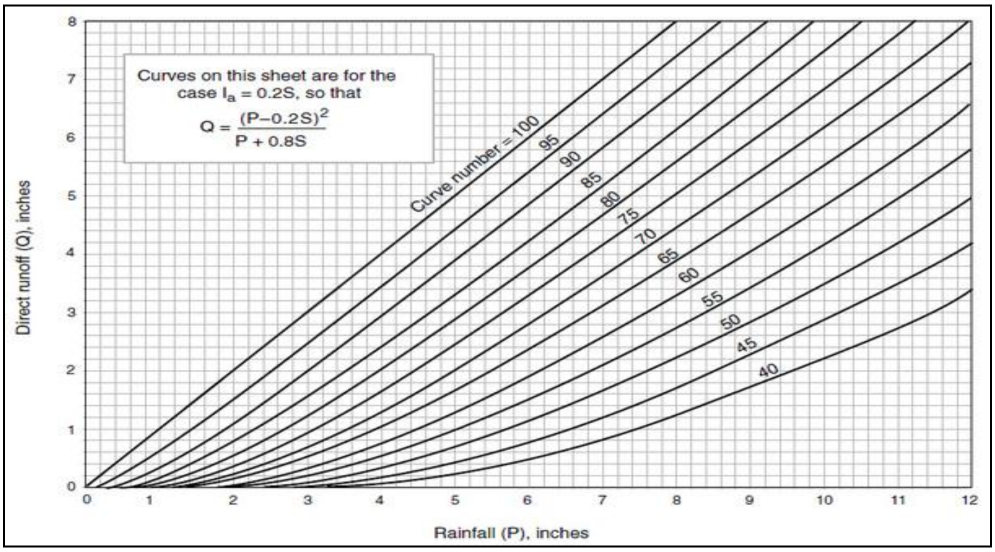

Figure 6- The SCS rainfall/runoff relationship (Soil Conservation Service) by (USDA, 1986)

Results and discussion:

1- Pumping test analysis

Time- drawdown data of the selected wells are shown in Figure-7, whereas the Table-3 shows the values of T and K as calculated by Jacob method as well as specific capacity of the above wells. These values significant variation in K values and hence T values reflecting the variable nature of the considered aquifer .Specific capacity values shows that the present well have variable productivity due to nature of the fracture dispersed as well as the water bearing layer thickness variations.

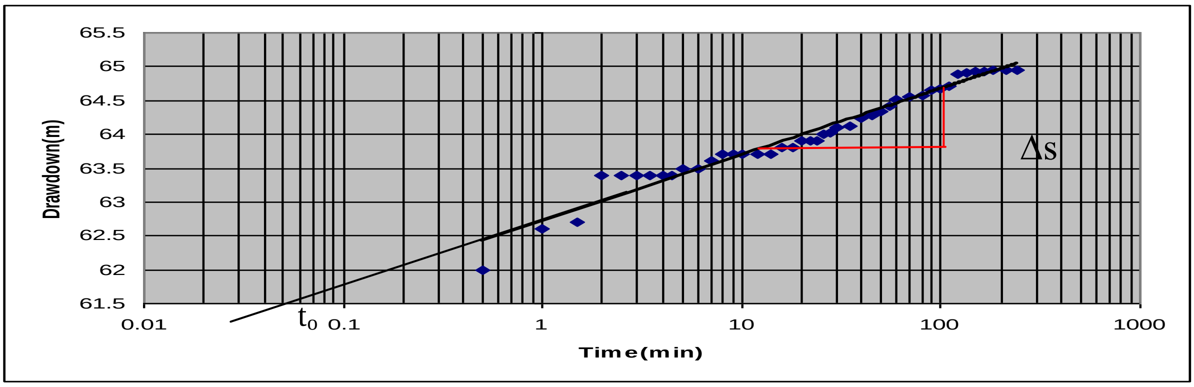

Figure 7a- Time drawdown plot of field data of an aquifer test for well no. 1

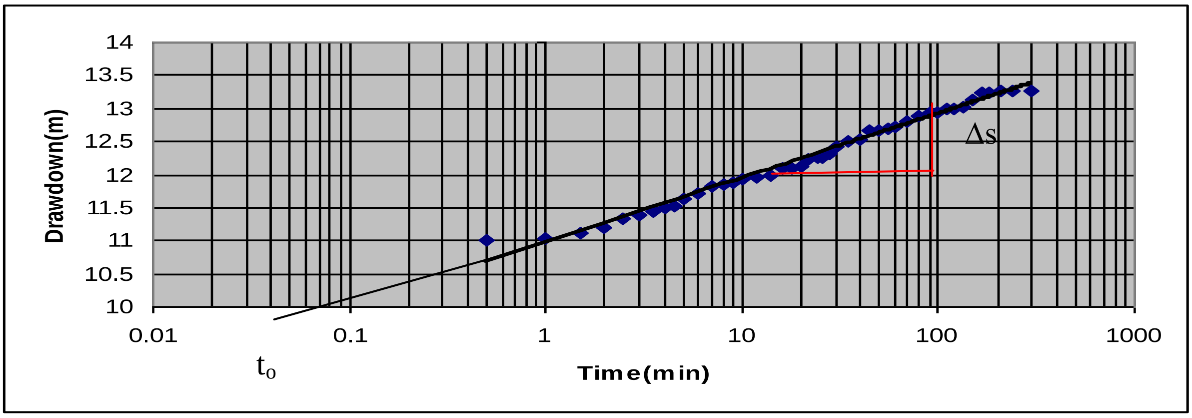

Figure 7b- Time drawdown plot of field data of an aquifer test for well no. 2

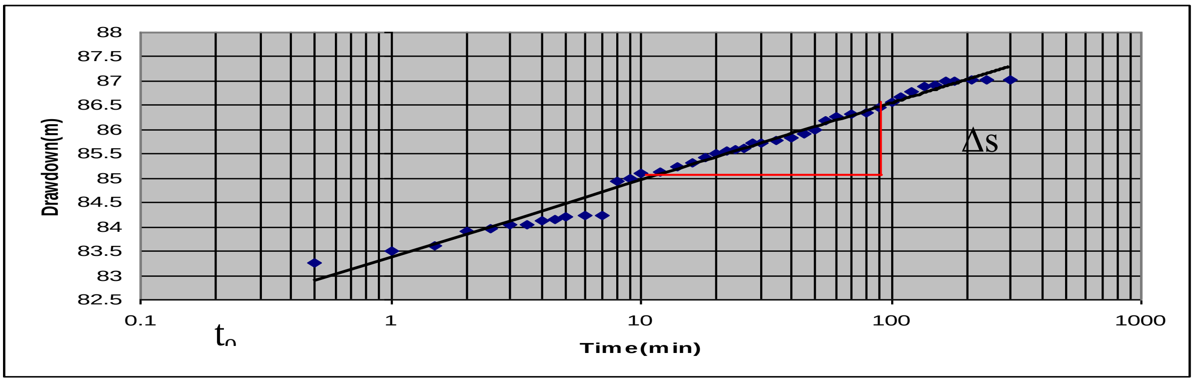

Figure 7c - Time drawdown plot of field data of an aquifer test for well no. 5

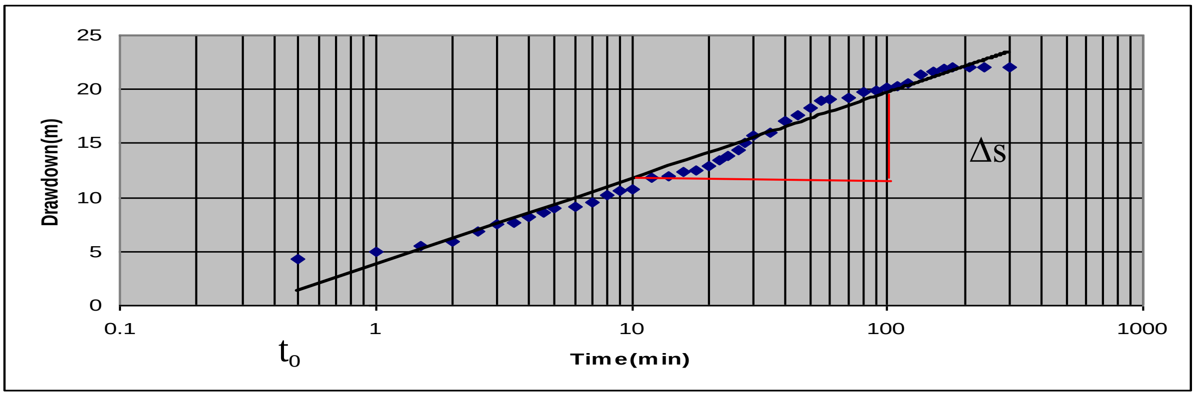

Figure 7d - Time drawdown plot of field data of an aquifer test for well no. 8

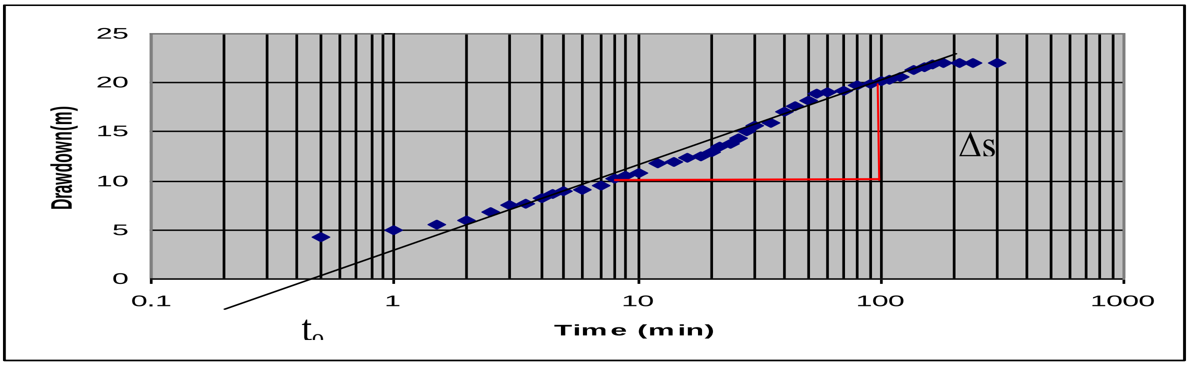

Figure 7e - Time drawdown plot of field data of an aquifer test for well no. 9

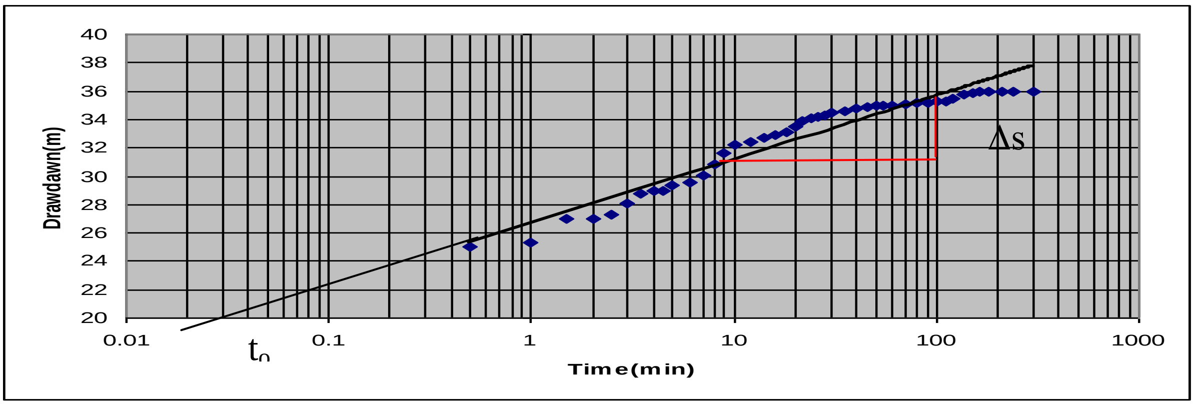

Figure 7f - Time drawdown plot of field data of an aquifer test for well no. 25

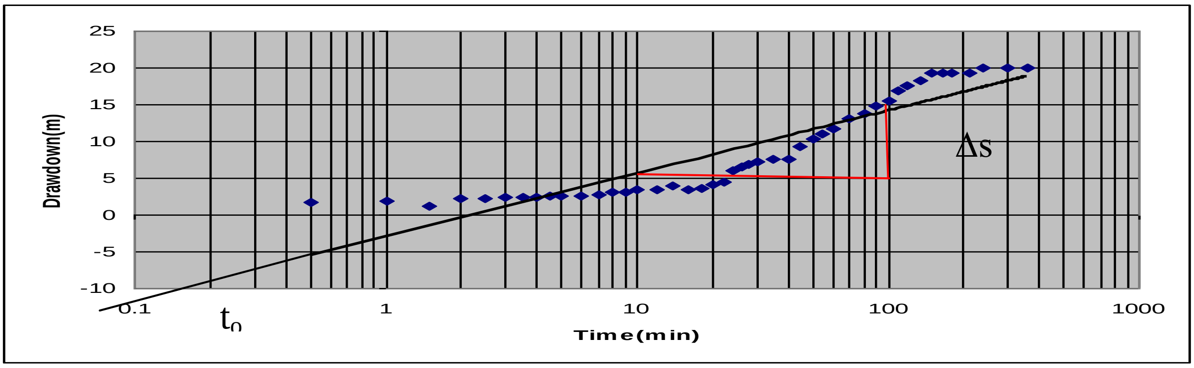

Figure 7g - Time drawdown plot of field data of an aquifer test for well no. 20

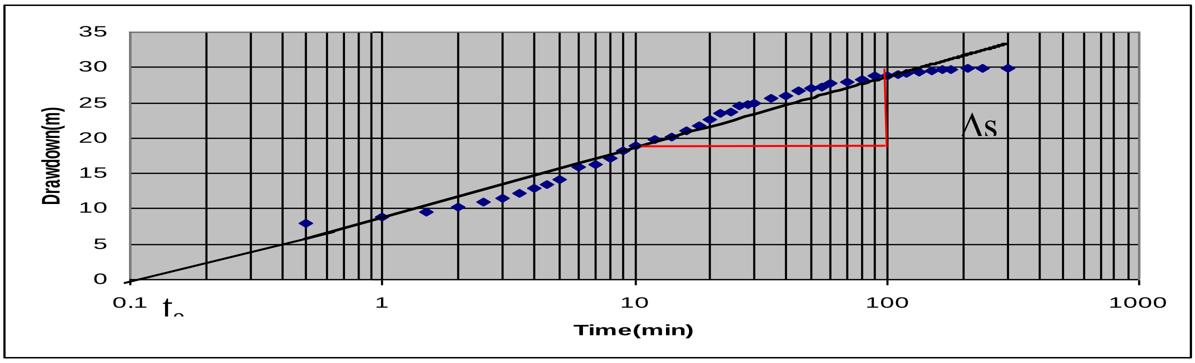

Figure 7h - Time drawdown plot of field data of an aquifer test for well no. 16

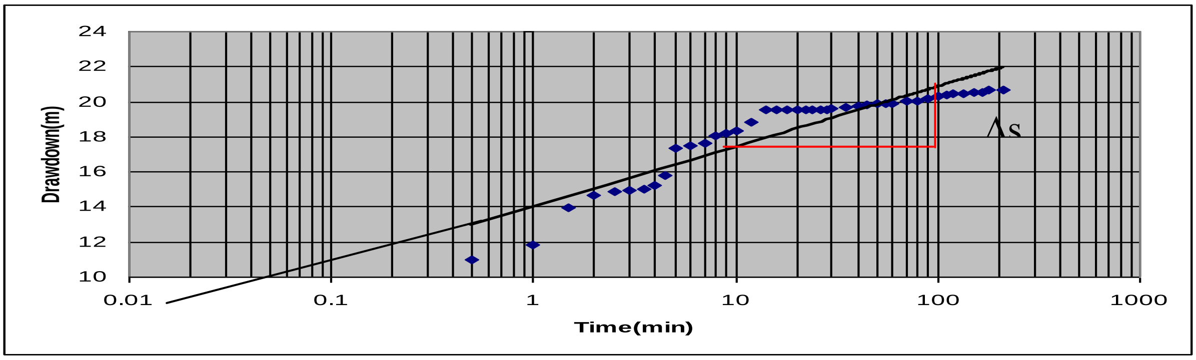

Figure 7i- Time drawdown plot of field data of an aquifer test for well no. 23

Table 3- Aquifer characteristics of pumped wells by Jacob's method

Well No.	T (m^2/day)	K(m/day)	S_c (m^2/day)	Draw down(m)
1	64.4	0.418	95.23	2.94
2	46.1	0.44	111	2.27
5	61.04	0.94	106.91	3.76
8	2.966	0.05	7.05	18.36
9	2.146	0.042	6.0845	17.77
16	1.506	0.025	3.96	10.96
20	2.441	0.047	6.59	18.29
23	9.5	0.120	26.72	21.79
25	6.665	0.133	11.22	9.7

2-Water balance

Values of potential evapotranspiration and effective rainfall of the used three meteorological stations are calculated by the approach of Penman-Monteith of FAO, 2006, where the results are shown in Table -4.The results show that the effective rainfall and reference evapotranspiration are ranged from o mm to 111.4 mm and 59.8 mm to 292mm respectively. According to the infiltration capacity calculations and Nikolov classification Tables-5, 6, 7, all of the present soils are of a group Tables-8. Results of Mehta's model application explain that the water surplus of the study area is 203.9 mm/year representing 29.4 % of the total rainfall Table-9. As the SCS method depends upon the nature land use, land cover and soil group, CN were determined using the Table-8,10 provided by NRCS [16] shows that Koisaniaq area have more than one CN values ,the weighted value of CN calculated by the formula below should be used

$$\mathbf{CN = A_1CN_1+A_2CN_2+\ldots\ldots+ A_nCN_n \ / \ A_1+A_2+\ldots\ldots. +A_n} \quad \mathbf{(10)}$$

Where:

$A_1+A_2+\ldots\ldots+A_n$ are the areas of various urban land uses.

CN_1, CN_2..., CN_n are the curve numbers.

Based on this formula, the curve number for the soil condition in the study area is equal to (60) Table- 11. Whereas the total amount of runoff (Rs) in the study area is equal = 128.72 mm/year Table-12, therefor recharge values (Re) can be calculated from the relation:

$$\mathbf{Ws = Rs + Re,\ Re = \sum Ws - \sum Rs,\ \ Re = 203.9 - 128.72,\ Re = 75.18mm} \quad \mathbf{(11)}$$

According to this model the total runoff is (128.72 mm) which is (18.56 %) of the total rainfall, while the groundwater recharge is (75.18 mm) which represent (10.84%) of the total rainfall.

Table 4- Mean annual values of effective rainfall and reference evapotranspiration for the study area

	Oct	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.
P_{eff}	24.0	49.3	97.0	111.4	94.5	82.6	66.5	17.5	1.4	0	0	0
Eto	157.2	106	82.46	59.8	71.8	133	188	243	263	292	247	209

Table 5- infiltration results for different location in the study area according to [5]

No.	**Location**	**X(UTM)**	**Y(UTM)**	**F(t) (mm/h)**	**Fc (mm/h)**	**Fo (mm/h)**	**K (1/h)**	**classification of infiltration capacity**
1	Harmota	464975	3991802	18	18	86	4.7	S-M
2	Hawawan khuaru	469500	3991800	20	20	79.07	2.35	M
3	Mizgotoka	468290	3991159	19.47	19.47	201.55	2.44	S-M
4	Koya center	466710	3993033	21.54	21.54	71.06	2.6	M
5	Shekhalan	459000	3993498	48.81	48.81	408.11	7.7	M
6	Hajikala	466322	3993020	31.04	31.04	482.42	6.2	M
7	Kelaspi	459510	3989090	19.9	19.9	397.18	3.93	S-M
8	Topzawa	462335	3993100	64.16	63.79	105.39	0.94	M-R
9	Bamurtkan	472925	3987150	12.7	12.7	139.9	2.53	S-M
10	Haibatsultan	469142	3994445	70	68.85	108.07	0.7	M-R
11	Mamqilinj	461188	3988120	9.7	9.6	159.85	1.46	S-M
12	Kamila	465120	3994656	37.2	37.2	183.14	2	M
13	Eskikoya	471535	3990125	19.4	19.14	200	2.58	S-M
14	Shila	464220	3988620	12	12	146.6	1.9	S-M
15	Huawan	470950	3993369	20.36	20.36	77.06	5.99	M
16	Abdalan	466627	3988305	4.94	4.82	113.72	1.36	S

Table 6- Infiltration results for some locations in the study area.

No.	Location	X(UTM)	Y(UTM)	F(t) (mm/h)	Fc (mm/h)	Fo (mm/h)	K (1/h)	classification of infiltration capacity
17	Kharaba	486941	3973142	23.1	23.1	81.6	2.5	M
18	Quritan	465654	3980832	68.7	68.0	110.14	0.8	M-R
19	Talaban	462968	3975776	9	9	67	3	S-M
20	Goktapa	455009	3992212	11.1	11.0	51.0	8.1	S-M
21	Pebazok	475289	3981952	49.40	49.45	84.89	2.0	M
22	Kanilala	458302	3982673	49.2	49.2	101.4	1.5	M
23	Mukharas	471121	3972523	58.70	58.7	120.9	1.5	M
24	Darbaru	462450	3985278	15.22	15.13	75.80	1.3	S-M

Table 7- Classification of infiltration capacity According to [15]

Infiltration capacity f(t)	Type
>160 mm/hour	Rapid (R)
60_160 mm/hour	Moderate _Rapid (M-R)
20_60 mm/hour	Moderate (M)
5_20 mm/hour	Slow _Moderate (S-M)
1.2_5 mm/hour	Slow (S)
<1.2	Very slow

Table 8- Description of (NRCS) Soil Groups.

Group	Decryption	Minimum infiltration rate (mm/h)
A	Deep sand. Deep loess, aggregated silt	> 7.6
B	Shallow loess , sandy loam	3.8-7.6
C	Clay loams, shallow sandy loam, soil low in organic content, soils usually high in clay	1.3-3.8
D	Soils that swell significantly when wet, heavy plastic clays , contain saline soils	0-1.3

Table 9 - monthly Water surplus for Koisanjaq Area.

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
p	25	80	120	145	116	112	75.6	18.3	1.4	0	0	0	693.3
Eo	157.2	106	82.4	59.8	71.8	133	188	243	263	292	247	209	
PET $_{crop}$	110	74.2	57.44	41.86	50.26	93.1	131.6	170.1	184.1	204.4	172.9	146.3	
APWL	0	-11.7	0	0	0	0	- 56.0	-207.7	-390.4	0	-172.9	-146.3	
P-PET	-85.0	5.8	62.6	103.1	65.7	18.9	- 56.0	-151.7	-182.7	-204.4	-172.9	-146.3	
sw	0.0	5.8	52.2	52.2	52.2	52.2	17.9	1.0	0.0	52.2	1.9	0.1	
dsw	0.0	5.8	46.4	0.0	0.0	0.0	- 34.3	-16.9	- 0.9	52.2	-50.3	-1.8	
AET	25	74.2	57.4	41.9	50.3	93.1	109.9	35.2	2.3	52.2	50.3	1.8	
Deficit	85	0.0	0.0	0.0	0.0	0.0	21.7	134.8	181.8	152.2	122.6	144.5	
Surplus	0.0	0.0	16.2	103.1	65.7	18.9	0.0	0.0	0.0	0.0	0.0	0.0	203.9
Units	All units in mm												

Table 10- Curve Number for Various Urban Land Uses [16].

Cover type and hydrologic condition	**Curve number for hydrologic soil group**			
	A	**B**	**C**	**D**
Lawns, open, spaces,parks, golf coursec				
Good conditions: Grass cover on 75% or more of the area	39	61	74	80
Fair conditions: grass cover on 50% t0 75% of the area	49	69	79	84
Poor conditions: grass cover on 50% or less of the area	68	79	86	89
Paved parking lots, roots, driveways, etc.	98	98	98	98
Streets and roads:				
paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Paved with open ditches	83	89	92	93
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Row hauses, town houses, and residental with lot sizes 1/8 ac or less (65% impervious)	77	85	90	92
Residental average lot size:				
1/8 ac or less (town houses) (65% impervious)	77	85	90	92
1/4 ac (38% impervious)	61	75	83	87
1/3 ac (30% impervious)	57	72	81	86
1/2 ac (25% impervious)	54	70	80	85
1 ac (20% impervious)	51	68	79	84
2 ac (12% impervious)	46	65	77	82

Table 11- Curve Number for Various Urban Land uses for Koi Sanjaq basin.

Cover type and hydrologic condition	Area Km2	CN	CN x Area
Fair conditions: grass cover on 50% t0 75% of the area	478	49	23422
Poor conditions: grass cover on 50% or less of the area	434	68	29512
Urban area	88	77	6776
Total	1000		
CN			60.00

Table 12- Runoff values calculated by SCS method

Month / Factor	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
Rainfall. P(mm)	25	80	120	145	116	112	75.6	18.3	1.4	0	0	0	693.3
Runoff Q(mm)	0	8.8	29.2	39.31	22.3	22.0	7.11	0	0	0	0	0	128.72
CN	60.00												

Cconclusions

- Infiltration rate measurement and calculation reveal that the study area soil are deep sand, deep loess and aggregated silt and mainly classify as A group soil according to hydrological soil classification.
- Flow system of the uppermost aquifer show normal pattern where the flow is from north and northeastern parts towards south and southeastern parts of Koisanjaq basin with nearly uniform hydraulic gradient. Great variation of the T and K values exhibits the significant variation in the aquifer lithology as well as the intensity and extent of fissures and fractures of the formation.
- Values of surface runoff form noticeable percent from the total rainfall reflecting the effects of Koisanjaq basin form, topography and soil characteristics. As value of groundwater recharge represent 10.84 % of the total rainfall therefore, the rainfall harvesting should be used to minimize the water losses as well as using the optimization technique to maximum the groundwater production rates.

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