Available online at www.scholarsresearchlibrary.com

Scholars Research Library

European Journal of Applied Engineering and Scientific Research, 2013, 2 (3):38-43
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041

Estimation of groundwater recharge at umudike watershed, Abia State -Nigeria

Adindu Ruth. U[1*], Igboekwe Magnus U[2]. , Isu John O[1]. and Igbokwe kelechi K[1].

[1] *Dept. of Physics/Electronics, Abia State Polytechnic, Aba. P.M.B 7166, Aba Nigeria*
[2] *Department of Physics, Micheal Okpara University of Agriculture, Umuahia, Nigeria*

ABSTRACT

The groundwater recharge at Umudike watershed was estimated for the year 2012 using soil water balance method. The watershed was divided into zones (blocks). The annual effective rainfall was 1909.8mm. Total number of rainfall days was 146. Peak months for rainfall were July and September. Evaporation peaked also in July with the value of 10.55mm. Runoff was observed to be higher than both cumulative infiltration and recharge. It ranged from 1656.8mm - 1866.8mm Potential evapotranspirtation was calculated to be 46.7mm.. Infiltration varied within the watershed. Male Hostel Block had the highest value (25.5cm) while Admin. Block has the lowest value (4.3cm). Other values include 20.1cm for Female Hostel, 15.3cm for science block and 13.9cm for poultry. 12.87cm layer of water was the highest amount of recharge. This occurred in the Male Hostel Block. Female Hostel Block had a recharge value of 12.07cm while no recharge occurred in both Admin and P.G Hostel Blocks. Other values were 3.05cm in the science block and 1.59cm in poultry/engineering block. Recharge was influenced by infiltration, runoff and the storage capacities of both the surface soils and sub soils.

Keywords: Recharge, Infiltration, Soil water, Rainfall, Evapo transpiration, Runoff.

INTRODUCTION

Groundwater is a natural resource which is replenishable either by natural or by artificial processes. Estimation of groundwater recharge is extremely important for proper management of groundwater systems. There are many different approaches for estimating recharge. Some estimate this rate by multiplying the magnitude of water-level fluctuations in wells, with the specific yield of the aquifer material [1], [2]. Some others use the processes of infiltrating recharge and fluxes on the water balance concept [3], [4], [5], [6]. The base-flow model approach is considered when water falls from the atmosphere to the ground surface and part of it forms surface runoff that flows into river courses. Soil water budget is used where the moisture content of the soil is tracked through time [7], [8].

Water balance modeling has the advantage of not only revealing mean values, but recharge can be estimated differentiated spatially and temporally. Additionally, water balance models are used to predict the impact of climatic change on the water resource or integrated in decision support systems for water resource management [9], [10]. They are also good tools for the recharge assessment, especially for the timing of recharge since its technique is based on meteorological and field data available at most locations. It incorporates insights gained from detailed studies and provides a practical methodology for recharge estimation in many situations [11].

The purpose of soil water balance calculations is to estimate daily or yearly value of the actual soil moisture content, which influences soil moisture uptake and crop transpiration. The basis of recharge estimation using this technique is that a soil becomes free draining when the moisture content of the soil reaches a limiting value called the field capacity; excess water then drains through the soil to become recharge [12].

To determine when the soil reaches this critical condition it is necessary to simulate soil moisture conditions over a period e.g. a year. This is achieved by representing the appropriate properties of the soil, the ability of crops to collect moisture from the soil and to transpire water to the atmosphere, and by including evaporation from bare soil. Infiltration to the soil zone is considered as an input since rainfall that passes through the ground surface infiltrates into the unsaturated zone. The water in an unsaturated zone will eventually infiltrate into the deeper zone of the ground due to gravity. Evapotranspiration is considered as output.

Umudike is fast growing in population due to urbanization owing to the institutions located in this area, with a lot of building cropping up. Borehole drillings are on the increase as the people of this area depend on groundwater for domestic and agricultural purposes. The sustainability of ground water systems relies on the amount of recharge by rainfall. The only source of recharge is by rainfall which occurs in the months of May to September while abstraction takes place every day. It therefore becomes necessary to estimate the ground water recharge of this area in order ascertain the rate at which it is being replenished so as to avoid over exploitation and also to make room for proper management of this resource.

MATERIALS AND METHODS

The method used in this recharge estimation is the soil water balance method (SWB). When SBW is used, it requires the estimation of the actual evapotranspiration (AET) from the root zone and the amount of water available (AW) to the plants. AW depends on the field capacity and the moisture holding properties of the soil. It also depends on the growth and harvesting periods of the crops [13]. The basis of this study is that soil becomes free draining when the moisture content of the soil reaches the field capacity then excess water drains. Infiltration to the soil zone is considered to be input while evapotranspiration is an output.

The processes considered that are directly affecting the root zone are: soil moisture content, infiltration, evapotranspiration and percolation. Any water percolating below the root zone is considered to meet the water table. The water shed is divided into zones (blocks). The cumulative infiltration and infiltration capacity of the surface soil within the water shed were determined experimentally in the field. If the effective precipitation exceeds the maximum infiltration capacity and surface storage capacity of the soil (field capacity), water runs off.

Meteorological data of Umudike was used to calculate the potential evaporation based on the Penmam monteith equation as given by [14]. Incoming rainfall was separated into interception, stem flow and through fall when entering the surface vegetation. Stem flow and through fall were summed up together as effective rainfall. Intercepted rainfall was lost by evaporation. Maximum interception storage of the vegetation was based on the land cover classes.

PENMAN- MONTEITH EQUATION

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\,(900/T+273)\,u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34u_2)} \qquad (1)$$

Where:

ET_0 = reference evapotranspiration (mm day^{-1}) R_n = net radiation at the crop surface (MJ m^{-2} day^{-1})
G = soil heat flux density (MJ m^{-2} day^{-1}) T = mean daily temperature at 2 m height (°C)
u_2 = wind speed at 2 m height (m s^{-1}) e_s = saturation vapor pressure (kPa)
e_a = actual vapor pressure (kPa) $e_s - e_a$ = saturation vapor pressure deficit (kPa)
Δ = slope vapor pressure curve (kPa °C^{-1}) γ = psychrometric constant (kPa °C^{-1})

Effective rainfall was separated into surface runoff and infiltration according to the equation below.

$$P_{(t)}^{cum} = I_{(t)}^{cum} + R_{(t)}^{cum} \quad (2)$$

Where:

$P_{(t)}^{cum}$ = the cumulative precipitation,
$I_{(t)}^{cum}$ = the cumulative infiltration, and
$R_{(t)}^{cum}$ = the cumulative runoff over the time period t.

And the infiltrating amount was added to the surface soil water (storage). Soil moisture conditions were determined in the laboratory. When the cumulative storage excess the surface soil moisture storage capacity, percolation takes place (table 2). The upper boundary of the root zone was kept at 30cm depth while the lower boundary was set at 1.5m. The relevant fluxes into and out of the soil system in the root zone were calculated. Soil water is lost due to actual evapotranspiration (AET) . AET was calculated using the crop coefficient factors and potential evapotranspiration (ET_O).

Change in Moisture storage content at this zone (ΔS), which is the amount of water been added or removed from what is stored in the root zone was calculated with the soil profile. AET_O was subtracted from the total moisture content of the subsoil to obtain (ΔS) table 3. Water is stored until the effective capacity is reached. Excess water percolates beyond the lower boundary of the rooting zone (set at 1.5 m) to become deep percolation or ground water. [15], [16].

The moisture storage capacity has been calculated by multiplying the residual with the root depth and the bulk density of the relevant vegetation zones. This gives maximum soil-moisture holding capacity (total layer of water) that must be satisfied before recharge can occur. Recharge was calculated by subtracting storage capacity from change in storage.

RESULTS

TABLE 1: UMUDIKE MONTHLY METEORIOLOGICAL DATA

LAT. 05^{0}29', LONG. 07^0 33', ALT. 122M AMSL.

2012	Rainfall (mm)		Temperature (^{0}C)		Evaporation (mm)	Relative Humidity (%)		Sunshine (hrs)
MONTH	AMOUNT	DAY	MAX	MIN	------	0900	1500	0.0
JAN	0.0	0	32	23	0.22	72	45	6.4
FEB	88.2	7	35	22	0.46	73	50	6.3
MAR	57.0	3	35	23	0.50	77	53	3.9
APRIL	142.0	17	33	24	0.82	76	59	6.1
MAY	233.7	16	32	24	4.70	84	70	5.0
JUN	213.0	14	31	23	9.25	87	77	3.5
JULY	362.0	24	30	23	10.55	86	75	3.4
AUG	161.8	19	30	24	6.10	88	78	2.2
SEPT	349.0	25	30	24	8.80	59	75	2.9
OCT	244.6	16	31	24	4.80	86	78	2.9
NOV	58.5	6	33	25	0.31	97	70	4.1
DEC	0.0	0	32	21	0.20	75	49	4.9
TOTAL	1909.8	147	384	280	46.71	1860	2279	51.6

TABLE 2: SURFACE SOIL MOISTURE STORAGE CAPACITY

Location	Infil - tration (cm)	Field capacity θ_{fc} (%)	Wilting point θ_{wp} (%)	Bulk density (g/cm^3)	Soil depth (cm)	Moisture storage capacity (cm)
Engineering /Poultry Block	13.9	19.8	4.9	1.6	30	7.2
Science. Block	15.3	16.9	2.9	1.7	30	7.1
Female Block	20.1	8.2	2.1	1.6	30	2.9
Male Hostel	25.3	17.1	3.5	1.8	30	7.3
P.G. Hostel Block	8.6	15.9	4.7	1.7	30	5.7
Admin Block	4.3	17.5	65.2	1.4	30	5.2

Moisture storage capacity. = $(\theta_{fc} - \theta_{wp})/100$ *Bulk density *Soil Depth

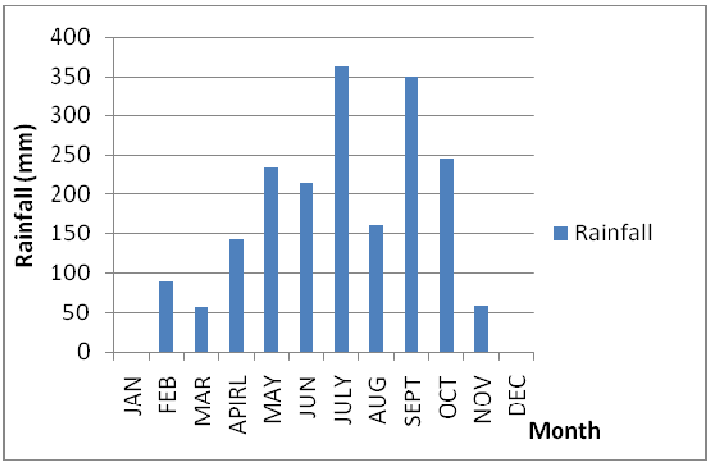

Fig.1: Monthly Rainfall distribution in Umudike

Table 3: Runoff, Infiltration, ΔS and Recharge compared

Location	Runoff (cm)	Runoff Co-efficient	Infiltration (cm)	ΔS (cm)	Recharge (cm)
Poultry Block	177.08	0.92	13.9	45.27	1.59
Science Block.	175.68	0.92	15.3	36.17	3.05
Female Hostel	170.88	0.89	20.1	28.07	12.07
Male Hostel	165.68	0.86	25.3	42.87	12.87
P.G Hostel	182.38	0.95	8.6	36.77	0.00
Admin Block	186.68	0.97	4.3	22.37	0.00

Effective. Rainfall =190.98cm Runoff Co-efficient = Runoff/ Effective Rainfall (ΔS) = change in storage Recharge(cm) = (,ΔS - Storage Capacity of sub-soil)

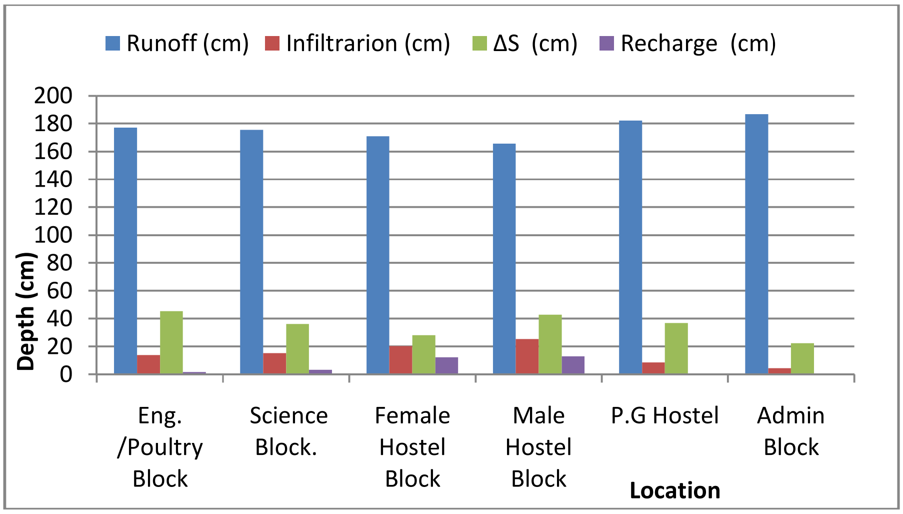

Fig.2: Runoff, Infiltration, ΔS and Recharge compared

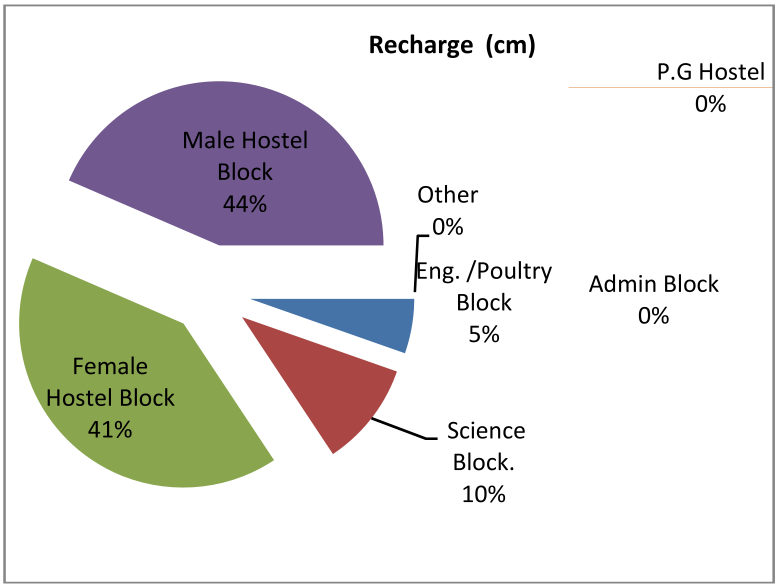

Fig 3: Recharge percentages of the locations

DISSCUSION

Table 1 shows the monthly meteorological data of Umudike for the year 2012. Rainfall peaked in the month of July with the value of 362.0mm, seconded by the month of September (349mm). These peaks have been reported by [17].

Evaporation peaked in the month of July with the value of 10.55mm. It depends on the available soil water and the infiltration capacity of the soil. When there is enough soil water, evaporation takes place, but if there was no rainfall evaporation will be at its minimum. This is illustrated in the months of December and January when rainfall amounts are 0.0mm , evaporation were only 0.2mm respectively (table 1). Total evaporation was 46.71mm for the year. Table 2 shows the variations in the cumulative infiltration within the watershed. Male Hostel Block has the highest value (25.5cm) while Admin. Block has the lowest value (4.3cm). Other values include 20.1cm for Female Hostel, 15.3cm for science block and 13.9cm for poultry.

Table 3 shows the variations in storage capacities of the soils. Moisture storage capacities were influenced by infiltration. Highest value occurred the Male Hostel Block (7.3cm) which had the highest cumulative infiltration value while Admin block, with the lowest cumulative infiltration value also had the lowest moisture storage value of 5.2cm. Change in moisture storage ranged from 22.33cm to 42.27cm.

Recharge was quite lower than both the runoff and infiltration. Runoff coefficients in this area was quite high. Table 3 shows that an average runoff coefficient of 0.9 was recorded. Table 3 and fig. 2 show that 12.87cm depth of water was the highest amount of recharge. This occurred in the Male Hostel Block. Female hostel Block had a recharge value of 12.07cm while no recharge occurred in both Admin and P.G Hostel Blocks. Other values in the year 2012 were 3.05cm in the science block and 1.59cm in poultry/engineering block. The results indicate that recharge was influenced by infiltration, runoff and the storage capacities of both the surface soils and sub soils. Zero recharge implies that the infiltrating water was either used up by the plants or was used to fill up the soil water deficit in these soils. [18] noted that infiltrating water that penetrates into the lower soil profiles is used first to replenish the soil moisture deficiency, while the excess moves downward to build up the water table. [19], [20] obtained similar results, using soil water Balance model in estimating the ground water recharge of Kalahari catchment of North-eastern Namibia. Their results recorded $8mma^{-1}$ and $74.6mma^{-1}$ respectively and noted that negative values of ΔS represent an increase in soil moisture deficit. [21] also obtained an annual recharge values that ranged from 0-$150mma^{-1}$ in his groundwater estimation work in Ngami land. He attributed his result to the distribution of soil, their moisture holding capacities and also to the vegetation cover.

CONCLUSION

The study estimated the groundwater recharge at Umudike watershed. The annual effective rainfall for the year 2012 was 1909.8mm. Total number of rainfall days was 146. Peak months for rainfall were July and September. Evaporation peaked also in July with the value of 10.55mm. Potential evapotranspirtation was calculated to be 46.7mm while runoff was observed to be high with an average coefficient of 0.9. Infiltration varied within the watershed, being lowest in the Admin Block and highest in the Male Hostel Block. This was influenced by the soil distribution within the watershed. Recharge was estimated to be between 0.0cm to 12.87cm in the year 2012. Recharge was influenced by infiltration, runoff and the storage capacities of both the surface soils and sub soils.

REFERENCE

[1]W.J. Avery, J. Donovan, and N. Ketchum, *Ground Water*, **1999,** 37**,** 332–337.
[2]J. Ketchum, J. Donovan and W. Avery, *Hydrogeology J.*, **2000**, 8,579–593.
[3]M. Louie, P.J Shelby and I. Smesrud, *Water Resour. Res.*, **2000**, 36, 2407–2416.
[4]R. Otto, *Hydrogeol J.* , **2001**, 9, 498–511
[5]H.F. Yeh, J.F. Chen and C.H Lee, *J. of the Chinese Institute of Environmental Engineering*, **2004,** 14:1–10.
[6]H.F Yeh, C.H Lee, J.F. Chen, W.P. Chen, , *Water Res*., **2007** , 34, 171–180.
[7]H. Gehrels, N.E. Peters and E. Hoehn, **2001**, IAHS Publication.
[8]L. Cheng-Haw, Y. Hsin-Fu and C. Jin-Fa, *Environ. Geol.* **2008**, 54, 1787–1797
[9]J.F. Chen, and C.H. Lee, *J. of the Chinese Institute of Engineers*, **2003**, 26, 321–332.
[10]C. Rodgers, N. van de Giesen, W. Laube, P.L Vlek. and E. Youkhana,
Water Resour. Manage, **2007**,. 21, 295–313
[11]K.R. Rushton, V.H. Eilers and R.C. Carter, **2006**), *Journal of Hydrology*, 318, 379–399
[12]W. R. Dripps and K. Bradbury, **2007**, *Hydrogeology Journal* 15, 433–444
[13]W.P. Chen, and C.H. Lee, *Environ. Geol.*, **2003**,. 44, 257–265.
[14]R. Allen, L.S. Pereira, D. Raes, and M.Smith, **1998,** , *Irrigation and Drainage Paper* 56. FAO, Rome, Italy p. 300
[15]C.H. Lee, W.P. Chen, and R.H. Lee, *J. Taiwan Water Conserv.,***2002,** 50,54–66.
[16]C.H. Lee, W.P Chen and R.H. Lee, *Environ Geol*., **2006,** 51,73–82
[17]M. U Igboekwe, V. V. S Gurunadha, and E. E Okwueze, *Hydrol. Process*. **2008**, 22(10), 1523-1531.
[18] Diamond, *Irish Geography*, **2004**, 36, 243-248.
[19]H. Klock,. Hydrogeologie und Umwelt, **2002**, 31,191–196
[20]W. Heike, D. Armin and U. Peter, *Water Resour. Manage*, **2008**, 22, 1143–1158
[21].P. Brunner, P. Bauer, M. Eugster and W. Kinzelbach, *J Hydrol*. **2004**, 294, 241–250