International Journal on Recent Researches In Science, Engineering & Technology
(Division of Computer Science and Engineering)
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Research Paper
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

Volume 4, Issue 12, December 2016.

JIR IF : 2.54
DIIF IF : 1.46
SJIF IF : 1.329

TO ASSESS THE SUSTAINABILITY OF GROUND WATER USING WATER BALANCE APPROACH OF VELLAR RIVER BASIN OF PUDUKKOTAI DISTRICT, TAMILNADU

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Abstract

This paper presents results related to water balance of the year 2014 of Vellar River basin of Pudukkottai district. The catchment covering an area of 533.86 km^2. Hydrology of the area was characters iced on the bases of land use, soil, slope, rainfall, temperature, evaporation, evopotranspiration and runoff using meteorological data. Different methods like rainfall coefficient method is used to determine the yearly distribution of rainfall, including wet season and dry season. The water balance model components of snow accumulation, direct runoff, snow melt, and evopotranspiration and soil moisture storage, runoff generation are calculated by method described by Thornthwaite Monthly water Balance model of USGS. This study reveals that there is water deficit in year 2014.

KEY WORDS: Water balance, Runoff, Precipitation, Snow fall, Evaporation

Introduction

Quantitative evaluation of water resources and their change under the influence of various factors can be predicted on the bases of water balance approach. With the water balance data it is possible to compare individual sources of water in a system over a different periods of time, and to establish the degree of the effect on variations in the water region it is also used to compute individual water balance components and the coordination of these components in the balance equation make it possible to identify deficiency in the distribution of observational station and to discover systematic error of measurements. This study provides an indirect evaluation of an unknown water balance components from the difference between the known components.

Geomorphology of Study Area

LOCATION: Pudukkottai is located at 10.38°N 78.82°E in the valley of river Vellar. Surface water is the major source of irrigation for about 82% of the net area irrigated. Vellar, Agniar, Ambuliyar, Karaiyur,

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Kundar and Pambar rivers drain the district. The district receives rainfall from both southwest (38%) and northeast (44%) monsoons [8]

The district is underlain by geological formations ranging in age from Archaean to Recent. Hornblende biotite gneiss, granite The important aquifers in the district are categorised into (i) fissured, fractured and weathered crystalline rocks and (ii) porous formations comprising Cretaceous, Tertiary and Quaternary sediments. Ground water occurs under phreatic to semi-confined conditions in fissured formations and productive fractures have been encountered down to a depth of 100 m bgl in the crystalline rocks. Ground water occurs in porous formations under water table and confined conditions.

CGWB has established network hydrograph stations in Pudukottai district to monitor the behaviour of water table and changes in the ground water quality of the shallow aquifers. In addition to this, CGWB has constructed 11 purpose built observation wells under World Bank Aided Hydrology Project for monitoring purpose (Hard rock 9 nos. and sedimentary area 2 nos.).

Hydrological Data

Pre-monsoon water levels are in the range of 5 to 10 m bgl, where as post-monsoon levels are in the range of 2-5 m bgl in the major part of the district. Analysis of water level fluctuation between May and January indicated a rise in water levels through out the district, mostly in

gneiss traversed by quartz veins and pegmatites occur in the western part of the district. Cretaceous sediments and Tertiaries occur in the eastern part of the district, while the recent alluvial deposits are seen along the major drainage courses and in coastal tract of the district.

the range of 0.20 – 5 m bgl. Long term water level fluctuation have been analysed for the period of post-monsoon which has indicated a rise in water levels in the range of 2 – 4 m in the major part of the district.

Central Ground Water Board has constructed 15 exploratory wells, 7 observation wells and 5 piezometers in the eastern part of the sedimentary tract of the district. Exploration has revealed the occurrence of potential aquifers down to a depth of 450 m bgl. The thickness of granular zones in the boreholes drilled down to the basement varies between 34 to 370 m. The cumulative thickness of the aquifers within 100 m bgl ranged from 6 to 39.5 m, where as it is between 21 m in the west and north to more than 250 m in the east and southeast in the depth range between 100 and 450 m bgl. Seven wells turned out to be flowing wells and the piezometric head ranged from 2.47 to 13.47 m agl with free discharges ranging between 12 and 33 lps. The discharges of the exploratory wells tested, ranged from 7.5 to 67 lps for a draw down ranging between 4.11 and 23.45 m[7].

The quality of ground water in the fissured formation in general, is potable and suitable for domestic and irrigation uses. In the porous formations, the quality of ground water is

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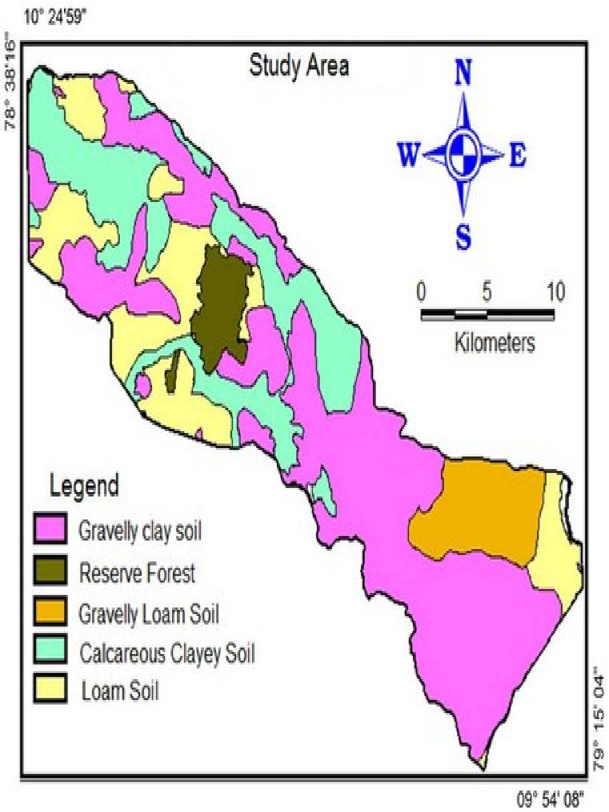
generally good and fit for both domestic and irrigation purposes except in the area south of Vellar River covering part of Arantangi and major part of Avudaiyarkoil taluks. Preliminary evaluation of resources based on GEC 1984 norms has indicated that the district has a considerable potential which has to be tapped in the all the blocks. The balance of groundwater resources available in the district is of the order of 76,034 ha m/year. In view of very low ground water development in all the blocks, shallow ground water levels and lack of major industries causing no ground water pollution, the district is not highly vulnerable to perils of over-exploitation, water logging or ground water pollution.



Study area of watershed

District :	PUDUKKOTAI
Taluk :	Kulathur Tirumayam Avudayarkoil

Region	:	4 Rivers draining in Bay of Bengal
Basin	:	A Kaniyakumari to Cauvery
Catchment	:	2 Between Vaigai and Cauvery
Sub Catchment	:	B Between Vaigai and Cauvery
Watershed	:	5 Vellar
Sub watershed	:	a,b,c, Vellar

METHODOLOGY

The first computation of the water-balance model is the estimation of the amount of monthly precipitation (P) that is rain (P_{rain}) or snow (P_{snow}), in millimeters. When mean monthly temperature (T) is below a specified threshold (T_{snow}), all precipitation is considered to be snow. If temperature is greater than an additional threshold (T_{rain}), then all precipitation is considered to be rain. Within the range defined by T_{snow} and Train, the amount of precipitation that is snow decreases linearly from 100 percent to 0 percent of total precipitation. This relation is expressed as:

$$P_{snow} = P \text{ X } \left(\frac{T_{rain} - T}{T_{rain-Tsnow}}\right)$$

$$P_{snow} = 0.8621 \, \frac{3.3-27.7}{3.3 -(-10)}$$

$$= 0.862\ (-1.835)$$

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$= -1.581mm$

P_{rain} then computed as :

$P_{rain} = P - P_{snow}$

$= 0.8621 – (-1.581)$

$= 2.444mm$

P_{rain} then is computed as: (2) based on an analysis of water-balance results for a number of sites, a useful value for Train is 3.3°C [5]. Useful values for T_{snow} appear to vary by elevation. For elevations below 1,000 m, T_{snow} = -10°C seems to work best, and for locations above 1,000 m T_{snow} = -1°C is more appropriate. (These values were determined from previous model calibrations during testing and evaluation for stream flow-gage sites in the conterminous United StatesP_{snow} accumulates as snow storage (*snostor*)

Direct Runoff

Direct runoff (DRO) is runoff, in millimeters, from impervious surfaces or runoff resulting from infiltration-excess overflow. The fraction (*drofrac*) of P_{rain} that becomes DRO is specified; based on previous water-balance analyses, 5 percent is a typical value to use . The expression for DRO is:

$DRO = P_{rain} \times drofac$

$DRO = 2.444 \times 0.1222$

$= 0.299mm$

Direct runoff (DRO) is subtracted from P_{rain} to compute the amount of remaining precipitation (P_{remain}):

$P_{remain} = P_{rain} - DRO$

$= 2.444 – 0.299$

$= 2.145mm$

SNOW MELT

The fraction of *snostor* that melts in a month (snow melt fraction, SMF) is computed from mean monthly temperature (T) and a maximum melt rate (*meltmax*); *meltmax* is often set to 0.5 [5]. The fraction of snow storage that melts in a month is computed as:

$$SMF = \frac{T - T_{snow}}{T_{rain} - T_{snow}} \times meltmax$$

$$= \frac{27.7-(-10)}{3.3—10} X\ 0.5$$

$$= \frac{277}{33} \times 0.5$$

$$= 4.197 \text{ mm}$$

If the computed SMF is greater than *meltmax*, then SMF is set to *meltmax*. The amount of snow that is melted in a month (SM), in millimeters of snow water equivalent, is computed as:

SM = *snostor* x SMF

SM is added to P_{remain} to compute the total liquid water input (P_{total}) to the soil.

Evapotranspiration and Soil-Moisture Storage

Actual evapotranspiration (AET) is derived from potential evapotranspiration (PET), P_{total}, soil-moisture storage (ST), and soil-moisture storage withdrawal (STW). Monthly PET is estimated from mean monthly temperature (T) and is defined as the water loss from a large,

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homogeneous, vegetation-covered area that never lacks water [7]. Thus, PET represents the climatic demand for water relative to the available energy. In this water balance, PET is calculated by using the Hamon equation:

$PET_{Hamon} = 13.97 \text{ x } d \text{ x } D^2 \text{ x } W_t$

Where PET_{Hamon} is PET in millimeters per month, d is the number of days in a month, D is the mean monthly hours of daylight in units of 12 hrs, and Wt is a saturated water vapor density term, in grams per cubic meter, calculated by:

$$W_t = \frac{4.95\ X\ e^{0.062\ X\ T}}{100}$$

$$= \frac{4.95\ X\ e^{0.062\ X\ 27.7}}{100}$$

$$= \frac{27.57}{100}$$

$$= 0.276 g/m^3$$

Where T is the mean monthly temperature in degrees Celsius.

$PET_{Hamon} = 13.97 \text{ x } d \text{ x } D^2 \text{ x } W_t$

$= 13.97 \text{ x } 365 \text{ x } (8.5)^2 \text{ x } 0.276$

$= 90069.6 mm/year$

When P_{total} for a month is less then PET, then AET is equal to P_{total} plus the amount of soil moisture that can be withdrawn from storage in the soil. Soil-moisture storage withdrawal linearly decreases with decreasing ST such that as the soil becomes drier, water becomes more difficult to remove from the soil and less is available for AET.

STW is computed as follows:

$$STW = ST_{i-1} - \left[abs(P_{total} - PET) X \left(\frac{ST_{i-1}}{STC}\right)\right]$$

$$= 115 - \left[abs(2.145 - 1528)\ X \left(\frac{80}{150}\right)\right]$$

$$= 115 - [abs(-900067.4) X\ 1.14]$$

$STW = 2193.41 \text{ abs} + 115$

Where ST_{i-1} is the soil-moisture storage for the previous month and STC is the soil-moisture storage capacity. An STC of 150 mm works for most locations.

If the sum of P_{total} and STW is less than PET, then a water deficit is calculated as PET–AET. If P_{total} exceeds PET, then AET is equal to PET and the water in excess of PET replenishes ST. When ST is greater than STC, the excess water becomes surplus (S) and is eventually available for runoff.

Runoff Generation

Runoff (RO) is generated from the surplus, S, at a specified rate (*rfactor*). An *rfactor* value of 0.5 is commonly used [5]. The rfactor parameter determines the fraction of surplus that becomes runoff in a month. The remaining surplus is carried over to the following month to compute total S for that month. Direct runoff (DRO), in millimeters, is added directly to the runoff generated from surplus (RO) to compute total monthly runoff (RO_{total}), in millimeters.

Summary and Conclusion

Monthly water-balance models have been used to examine the various components of the hydrologic cycle (for example, precipitation, evapotranspiration, and runoff).

$P_{snow} = 1581.9mm$

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P_{rain} = 2444mm

DRO = 298656.8mm

P_{remain} = -296212.8mm

P_{total} = -29621.2mm

PET = 8357 mm

AET = 27313.3mm

Since the sum of P_{total} and STW is less than PET, then the study area has a water deficit of 35670.28mm. This is due to hard rock terrains having poor storage capacity. The climatic condition also accelerates the loss of water due to Evaporation and Evapotranspiration.

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Received: 3.12.2016
Accepted: 27.12.2016