DEVELOPMENT OF A MODEL FOR GROUNDWATER ESTIMATION

It is intended to find the temporal groundwater availability in a particular area considering the dynamic nature of groundwater. All the inflows from the adjacent aquifers and the outflows to the adjacent aquifers due to withdrawal and recharge of groundwater are required to be taken into account while evaluating the dynamic ground water storage.

The monthly availability of groundwater is to be assessed using the given recharge and withdrawal data.

Methodology :

The area of a district is divided into a number of circular zones so as to cover the entire area. The centre of the each circle defines a local origin of a polar co-ordinate system. Let the radius of a circular zone be 'R'. Let 'i' be an abstraction point whose polar co-ordinates are (r_i, θ_i). The cumulative inflow to the aquifer from the adjacent area across the circle upto time 't' due to continuous withdrawal at unit rate at point 'i' is given by

$$K(r_i,\theta_i,R,t)=\int_0^{2\pi}\int_0^{t}\frac{R}{2\pi}\,\frac{e^{-\frac{[R^2+r_i^2-2Rr_i\mathrm{Cos}(\theta_i-\theta)]}{4\beta\tau}}}{[R^2+r_i^2-2Rr_i\mathrm{Cos}(\theta_i-\theta)]}\,[R-r_i\mathrm{Cos}(\theta_i-\theta)]\,d\tau\, d\theta$$

in which,

β = T/ϕ, the hydraulic diffusivity of the aquifer,

T = transmissivity of the aquifer, and

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ϕ = storage coefficient.

Integrating with respect to τ

$$K(r_i, \theta_i, R, t) = \int_0^{2\pi} \frac{R d\theta}{2\pi} \frac{[R - r_i \mathrm{Cos}(\theta_i - \theta)][t\, e^{-C/t} - C E_i(C/t)]}{[R^2 + r_i^2 - 2 R r_i \mathrm{Cos}(\theta_i - \theta)]} d\theta$$

in which,

$$C = \frac{R^2 + r_i^2 - 2 R r_i \mathrm{Cos}(\theta_i - \theta)}{4\beta}, \text{ and}$$

$$E_i(C/t) = \int_{C/t}^{\infty} \frac{e^{-u}}{u} du.$$

A numerical integration has to be carried out to evaluate the integral.

If unit withdrawal takes place at the first unit time at the i^{th} abstraction point, and no withdrawal after that, the cumulative flow at the end of the n^{th} time step across the circle is given by

$$\delta_{Ii}(n) = K(r_i, \theta_i, R, n) - K(r_i, \theta_i, R, n-1)$$

and

$$\delta_{Ii}(1) = K(r_i, \theta_i, R, 1)$$

The cumulative inflow at the end of n^{th} time-step across the circle, $CUMI_i(n)$, due to varying abstraction from the i^{th} well is given by

$$CUMI_i(n) = \sum_{\gamma=1}^{n} QP_i(\gamma) \delta_{Ii}(n - \gamma + 1)$$

in which,

$QP_i(\gamma)$ = Quantity of water pumped during γ^{th} time-step at i^{th} well.

If there are 'M' abstraction points, then total inflow up to the end of n^{th} time-step, CUMI(n), due to all withdrawal is expressed by

$$CUMI(n) = \sum_{i=1}^{M} \sum_{\gamma=1}^{n} QP_i(\gamma)\delta_{Ii}(n-\gamma+1)$$

Similarly total outflow from the circular zone at the end of n^{th} time-step due to recharge $QR_j(\gamma)$ occurring during γ^{th} time-step at j^{th} recharge point, $j=1,2,..,N$, and $\gamma=1,2,..,n$, is given by

$$CUMO(n) = \sum_{j=1}^{N} \sum_{\gamma=1}^{n} QR_j(\gamma)\delta_{Oj}(n-\gamma+1)$$

$\delta_{Oj}(n)$ and $\delta_{Ii}(n)$ are identical.

If the number of abstraction points and recharge points inside the circular zone are M_C and N_C respectively, then the amount of draft and recharge at the end of n^{th} time-step will be

$$CUMQP(n) = \sum_{i=1}^{M_C} \sum_{\gamma=1}^{n} QP_i(\gamma)$$

$$CUMQR(n) = \sum_{j=1}^{N_C} \sum_{\gamma=1}^{n} QR_j(\gamma)$$ respectively.

The groundwater availability in that particular zone at the end of nth time-step can be expressed by

$$GW(n) = CUMQR(n)-CUMQP(n)-CUMO(n)+CUMI(n)$$

or

$$GW(n) = \sum_{j=1}^{N_C} \sum_{\gamma=1}^{n} QR_j(\gamma) - \sum_{i=1}^{M_C} \sum_{\gamma=1}^{n} QP_i(\gamma)$$

$$- \sum_{j=1}^{N} \sum_{\gamma=1}^{n} QR_j(\gamma)\delta_{Oj}(n-\gamma+1)$$

$$+ \sum_{i=1}^{M} \sum_{\gamma=1}^{n} QP_i(\gamma)\delta_{Ii}(n-\gamma+1)$$

Similar solutions for all the circular zones, by which the area is approximated, is obtained and algebraic addition of all these availability of groundwater will give the required groundwater storage available for the district.

ESTIMATION OF RECHARGE AND DRAFT:

The details of the water balance components which are considered in the groundwater assessment are as follows:

MONSOON RECHARGE,

The recharge taking place during monsoon period, i.e. from June to September, is considered as monsoon recharge.

Monsoon Recharge Due to Rainfall,

The groundwater availability in that particular zone at the end of nth time-step can be expressed by

$$GW(n) = CUMQR(n) - CUMQP(n) - CUMO(n) + CUMI(n)$$

or

$$GW(n) = \sum_{j=1}^{N_C} \sum_{\gamma=1}^{n} QR_j(\gamma) - \sum_{i=1}^{M_C} \sum_{\gamma=1}^{n} QP_i(\gamma)$$

$$- \sum_{j=1}^{N} \sum_{\gamma=1}^{n} QR_j(\gamma)\delta_{Oj}(n-\gamma+1)$$

$$+ \sum_{i=1}^{M} \sum_{\gamma=1}^{n} QP_i(\gamma)\delta_{Ii}(n-\gamma+1)$$

Similar solutions for all the circular zones, by which the area is approximated, is obtained and algebraic addition of all these availability of groundwater will give the required groundwater storage available for the district.

9.2.0 ESTIMATION OF RECHARGE AND DRAFT:

The details of the water balance components which are considered in the groundwater assessment are as follows:

9.2.1 MONSOON RECHARGE,

The recharge taking place during monsoon period, i.e. from June to September, is considered as monsoon recharge.

9.2.1.1 Monsoon Recharge Due to Rainfall,

Monsoon recharge due to rainfall can be calculated either by using the water table fluctuation approach or rainfall