Automated Ground-water Management & Sustainable Usage Support

KANISHK TANTIA, MEHUL NAKRA, MANVENDRA SING BAIS
Affiliation: B.Tech (CSE) undergraduate, Acropolis Institute of Technology and Research, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Indore Bypass Road, Mangliya Square, Mangliya, Indore, Madhya Pradesh 453771, India.
.

Abstract:- Ground-water management is a manual process in India. Groundwater depletion puts a heavy cost to farmers, domestic consumers, big industries, government and rainwater harvesting in unimaginable ways (Big fat electricity bills, land subsidence and uneven distribution and even it determines life and death). If this is addressed with proper monitoring and data collection, a huge beneficial inference can be drawn out with the help of analytics which can help in the prevention easier than its cure. Currently in India, the government agencies are measuring groundwater trends based on the observation wells. These observation wells are limited in number whereas the common usage consists of a huge number of borewells. If these borewells could be monitored then the amount of data generated will aid in predicting some better sustainable practices.This paper describes a strategy to use piezoelectric sensors in the borewells to get continuous water level reading. Apart from the consumed amount of water by the users, Integrating this data along with the other factors which causes the water level to fluctuate inside a borewell. Calculating this will be used for modelling a sustainable model for water health in the region of application.

Key-words:- Piezoelectric, Aquifer, Integrated hydrological modelling (Water-g), Gamification, Water-g water flow model.

1. Introduction

Groundwater is a major component of water resources management and planning in developed basins, arid and semi-arid regions. The major utility of groundwater is that it being in the ground can act as a transitional layer between the on surface water bodies and the age old aquifers, which are huge reserves of freshwater, found in the Earth’s crust. This reserve source of water which is known as groundwater can be used when the surface bodies fell short in fulfilling the demands, Groundwater can be the only source of water to meet these demands in semi-arid or arid climates. Therefore, any water resources planning studies which are carried out for a developed basin must include the management of both surface and subsurface water resources while addressing the dynamic interaction between them. There are a lot of factors affecting the flow rate of water in the borewells. A few of them could be hydrostatic pressure due to the connected source water body. Since water is for all so as it is used with many alterations and modifications according to the need and requirement of the stakeholder. A farmer requires a certain amount of water at a particular rate at a particular location whereas a house holder requires a certain quality of non-stop water supply for personal usage. Groundwater management and planning are generally affected by all these factors and a proper management plan must address many of these issues.Based on the different requirements of different stakeholders an integrated hydrological modeling is required in order to provide the best possible data. In India, a lot of man power is consumed in this process of groundwater level collection, interpretation and execution to make the hydrological unit models . These models are mathematically less sound and are less accurate for the purpose of predictions. If this process gets automated then it can save the time and resources of training these people directly increasing the accuracy of the system and providing real-time values to the stakeholders. Pure groundwater models

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

simulate the flow in the aquifer but all stresses on the groundwater system must be calculated outside the model . The dynamic interdependence between groundwater and the rest of the hydrologic cycle as well as the regulatory environment is not simulated dynamically and must be pre-defined.On the other hand, integrated hydrologic models incorporate the simulation of groundwater and most or all of the flow processes from the rest of the hydrologic cycle. They simulate groundwater flow dynamics and other flow processes at varying degrees of complexity using different approaches.Groundwater planning must be undertaken by taking into consideration the source of the water and the sink. Water is a monetized commodity and hence wherever the stakeholders move, these sources and sinks are reshaped every time according to it. In developed basins, these sources and sinks are shaped by agricultural and urban development and the regulatory environment dictating the use of water resources as much as by natural forces such as precipitation and evapotranspiration. For instance, the amount of pumping is affected by the climate, agricultural crop characteristics, farm water management parameters, and availability of stream flows which are partially dictated by the operation of the upstream reservoirs and regulations dictating surface water use and in-stream flows. Therefore, to perform a comprehensive groundwater resources analysis and planning study, it is generally necessary to use more than one type of model and simulate not just the groundwater flow dynamics but also the entire hydrologic system, reservoir operations, agricultural water demands, etc. This paper discusses covering all such borewells which are constantly in use and how to save water through them.

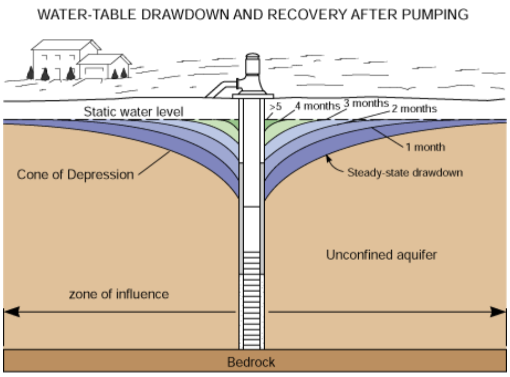
2. Materials and methods

Water-g system uses groundwater fluctuation levels which occur naturally as well as post pumping the water out. These fluctuation values are then separated in 2 categories i.e fluctuation due to pumping and natural geological fluctuation. This natural geological fluctuation comprises a few other models like the groundwater flow , Fluctuation due to lakes, streams and other contributing factors. Since the groundwater networks are interconnected with aquifers, streams, lakes and other water bodies of the area, it becomes important to mathematically model these phenomena so that the Artificial intelligence model could get better parameters to work on.

A. Fluctuation due to pumping

Withdrawal of a thousand gallons per minute (a common pumping rate for high volume wells) is an unnaturally rapid change in a groundwater system, and results in some major perturbations of the water table. Initially, water level drops very rapidly in the immediate vicinity of the well. This lowering of the water table is known as drawdown, and may amount to many tens of feet (fig.1). This is why thinly saturated zones are unsuitable for high volume pumping even if substantial water is present -- the saturated thickness must be large enough so that the pump can remain completely submerged at maximum drawdown.

Fig.1



B. Groundwater

Simulation of groundwater flow is at the heart of water-g (fig. 2). Three-dimensional, transient groundwater flow is simulated in complex,

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

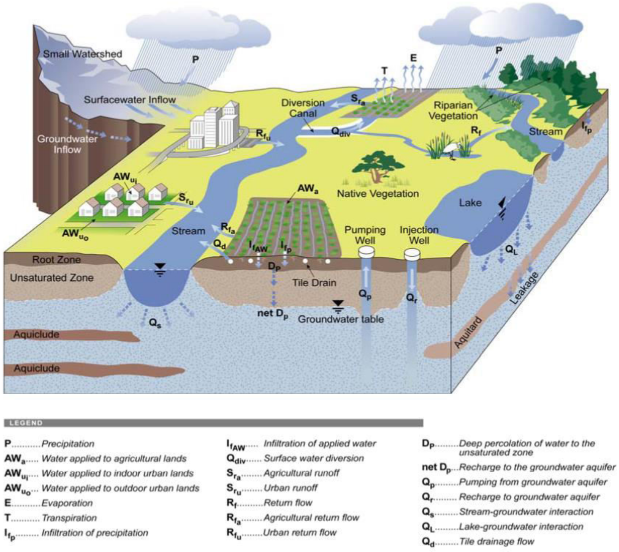
multi-layered aquifers. The aquifer layers can be a combination of confined, unconfined, and leaky layers separated by aquitards or aquicludes. Integrated hydrological modelling (Water-g) can handle aquifer layers that pinch out and disappear at sections of the groundwater basin. Through the simulation period confined layers can become unconfined, or unconfined layers confined, as the simulated groundwater heads fluctuate in response to the stresses. Three-dimensional groundwater flow is represented by the depth-integrated conservation equation at each aquifer layer interacting with the layers above and below them through leakage terms:

$$\partial S_s h / \partial t = {}^{*}\nabla KD {}^{*}\nabla h + I_u L_u (h^u - h) + I_d L_d \, h^d$$

$$- h + q_o + q(h), \quad (1)$$

where h = h(x,y,t) = groundwater head in an aquifer layer, (L); K = K(x,y) = saturated hydraulic conductivity, (L/T); D = D(x,y,t) = saturated thickness of the aquifer layer, (L); S_s = S_s(x, y, t) = storativity which is equal to the storage coefficient for a confined aquifer and specific yield for an unconfined aquifer, (dimensionless); h^u = h^u(x, y, t) = groundwater head at the aquifer layer that is above the layer being considered, (L); L_u = L_u(x, y) = leakage coefficient between the layer considered and layer above, (1/T); I_u = indicator depending on the aquifer layer, equals 0 for the top-most aquifer layer and 1 for other layers, (dimensionless); h^d = h^d(x, y, t) = groundwater head at the aquifer layer that is below the layer being considered, (L); L_d = L_d(x, y) = leakage coefficient between the layer considered and layer below, (1/T); I_d = indicator depending on the aquifer layer, equals 0 for the bottom-most aquifer layer and 1 for other layers, (dimensionless); q_o= q_o(x, y, t) = non-head-dependent sources and sinks, (L/T); q(h) = head-dependent sources and sinks, (L/T); ${}^{*}\nabla$ = del operator, (1/L); x = horizontal x-

Fig. 2



coordinate, (L); y = horizontal y-coordinate, (L); and t = time, (T).

C. Streams

Complex, dendritic stream channel networks are described by connecting the relevant nodes of the finite element grid, and the stream flows can be simulated using either the "instantaneous flow" approach or the kinematic wave approach. In both approaches, the following conservation equation is solved: $\partial Qs/\partial xs + \partial A/\partial t = Qsin - Qsout - Qsint / Ls, \quad (2)$

where Qs = stream flow, (L3/T); A = stream flow cross-sectional area, (L2); Ls = stream channel length, (L); Qsin = all inflows into the stream along its length, Ls, (L3/T); Qsout = all outflows from the stream along its length, Ls, (L3/T); Qsint = stream-aquifer flows along its length, Ls, (L3/T); and xs = spatial coordinate along the length of the stream, (L). The Qsin term in Equation (2) consists of all inflows into the stream that Integrated hydrological modelling (Water-g) can simulate: inflows from upstream channels, rainfall runoff, agricultural and urban return flows, inflows from small watersheds that are adjacent to the model boundary, inflows from tile drains, inflows from river bypass systems, inflows from upstream lakes, and inflows pre-specified by the user as time series input data. The Qsout term includes outflow to the downstream channel, surface water diversions to meet any water demands, water taken out of the stream into bypass channels, and evapotranspiration due to riparian vegetation. All of these inflow and outflow terms are optional depending on the specific application of Integrated hydrological modelling (Water-g). In the instantaneous flow approach, it is assumed that a flow pulse travels instantaneously within the simulated stream network. This approach is applicable when the simulation time step is known to be larger than the characteristic time scale of the stream flows within the modeled basin. For instance, if it is known that stream flow travels from the upstream end to the downstream end of the stream network within the model domain within several days and a monthly simulation time step is selected for modeling, then the instantaneous flow approach can be safely used. Using this approach renders the left-hand side of Equation (2) zero:

$$0 = Qsin - Qsout - Qsint. \quad (3)$$

In the kinematic wave approach, the slope of the energy line is represented by the stream channel slope. The implementation of kinematic wave approach in Integrated hydrological modelling (Water-g) is discussed in detail. This approach can be used when the stream flow does not travel through the simulated stream network within a single simulation time step requiring representation of the change in stream storage. Stream–aquifer interaction is calculated at each stream node and the corresponding groundwater node as a head-dependent boundary condition for both systems. To convert stream flows to stream stage in order to calculate stream–aquifer interaction, the relationship between streamflow, Qs, and the stream stage is defined through user-specified rating tables specified at each stream node for the instantaneous flow approach. For the kinematic wave approach, this relationship is defined by Manning's equation . Equation (2) is discretized using the fully implicit finite difference scheme with backward differencing . The resulting set of non-linear algebraic equations is combined with those obtained from the discretization of the groundwater equation and solved simultaneously.

D. Lakes

Lakes are represented in Integrated hydrological modelling (Water-g) using the following conservation equation:

$$\partial Sk/\partial t = Qkin - Qkout - Qkint, \quad (4)$$

where Sk = lake storage, (L3); Qkin = all inflows into lake, (L3/T); Qkout = all outflows from the lake, (L3/T); and Qkint = lake–aquifer flows, (L3/T). The Qkin term in Equation (4) includes precipitation, inflows from streams either through streams flowing directly into the lake or diversions from streams into the lake, rainfall runoff, agricultural and urban return flows, and inflows from upstream lakes. The Qkout term includes lake surface evaporation, and lake outflow if the lake elevation exceeds a pre-specified maximum lake elevation. Similar to stream–aquifer interaction, lake–aquifer interaction is simulated as a head-dependent boundary condition. Lakes are identified by specifying the corresponding finite element cells. Based on the finite element nodes associated with these cells and the ground surface elevation specified at these nodes, Integrated hydrological modelling (Water-g) internally generates a storage versus lake–surface–elevation rating table with the maximum storage calculated at the user-specified maximum lake elevation, which can be a time series input. Equation (4) is discretized in time using a fully implicit method for each lake and the resulting set of algebraic equations is solved, along with equations representing groundwater and stream flows simultaneously, using the Newton–Raphson method. The many optional inflows into the lakes that can be represented by Integrated hydrological modelling (Water-g) make the lake component quite versatile. It has been used in the past to simulate natural and man-made lakes, managed wetlands, ponding operations in rice fields, and spreading basins used in managed aquifer recharge operations.

3. How Water-g system works

Deeper the water levels, more is the pumping and hence higher the cost to bear. To keep water sustainable enough, a credit based app to every stakeholder is proposed to be used which is having a strong ML and DL background. The first 2 stages are the most critical stages. Using piezoelectric sensors, constant groundwater level monitoring can be done . An IoT enabled system is set up for the region of experiment. After covering all the commercial as well as private borewells with this system a huge amount of data is generated. Using data analytics of different systems, we are giving you a comparable and competitive analysis of water usage along with safe usage limits. Presently these are static, so it is not right to say it'll work for another geographical region as well. The system installed on the ground. The left side has a flowmeter and a piezoelectric sensor. The part of the image with (fig.3) silver background shows 2 variables 'X' & 'Y' . X giving us the pumped out or consumed water Y is time-logged fluctuation in ground water level, Using fuzzy neural networks (fig 3) in a course of time will recognize the usage habits of the stakeholders and according to the flowrate of groundwater , lakes and streams it can generate a sustainable fluctuation value. This will give the stakeholders a quantity of water in litres which will be their tentative usage limit. The problem of water scarcity is known to all but there's no action plan. Here, in such conditions, where the society is unable to take collective action, a psychological shift could play a key role.

4.

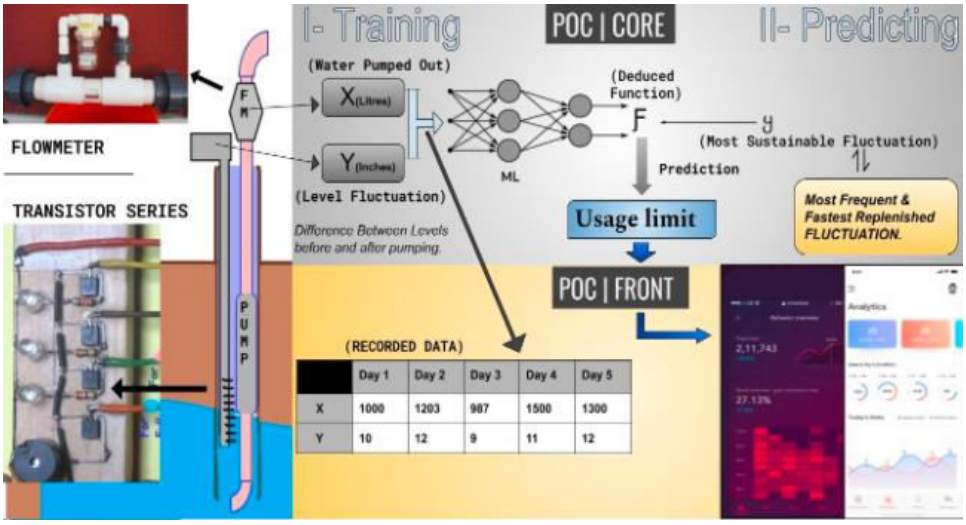


Fig. 3

Conclusion

Groundwater is an integral component of the hydrologic cycle and water resources management in developed basins. There is interdependence between groundwater resources management, climate, surface water resources availability and management, economics, as well as legal and social constraints on water management. Therefore, in a developed basin, groundwater resources management is generally complex and requires attention to the co-evolution of groundwater resources with climate, surface water resource management, and economics and residential water management tools. Integrated hydrological modelling (Water-g) is prescriptive because it can calculate stresses on the groundwater and streams dynamically in terms of pumping and diversions, respectively, to meet dynamically computed water demands. It is at the same time descriptive because once these stresses are calculated, Integrated hydrological modelling (Water-g) can route the water through the hydrologic system to describe where and how fast the water is moving. This feature of Integrated hydrological modelling (Water-g) allows the simulation of the spatio-temporal evolution of the groundwater in response to changing climate, land use distribution, and surface water management. This paper briefly describes the simulation methods used in Integrated hydrological modelling (Water-g) and provides several applications highlighting its effectiveness in groundwater resources analysis, management, and planning.

5. References

[1] Emin C. Dogrul *, Charles F. Brush and Tariq N. Kadir, "*Groundwater Modeling in Support of Water Resources Management and Planning under Complex Climate, Regulatory, and Economic Stresses*", Water MDPI, pp 1-22, 2021.

[2] Jyrkama, M.I.; Sykes, "*J.F. The impact of climate change on spatially varying groundwater recharge in the grand river watershed (Ontario). J. Hydrol*". 2007, 338, pp 237–250.

[3] Karamouz, M.; Kerachian, R.; Zahraie, B. *"Monthly water resources and irrigation planning: Case study of conjunctive use of surface and groundwater resources"*. J. Irrig. Drain. E 2004, 130, pp 391–402.