Gradual Variation Analysis for Groundwater Flow in the District of Columbia

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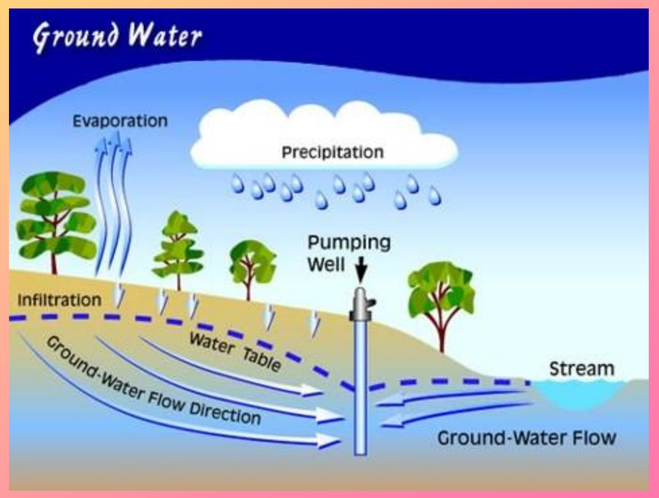
OBJECTIVE

The current method of flow estimation mainly uses the ground flow equation, which is a partial differential equation. Software systems such as MODFLOW can only solve 2D equations and pass the data vertically to form a 3D volume. Research on the 3D models of groundwater flow has fundamental and practical importance to hydrogeology.

The objective of this study is to establish a 3D model using discrete mathematics, especially graphical and graph-theoretical methods, to compute groundwater flow.

MATERIAL AND METHOD

Schematic representation of ground water (www.norcalblogs.com):



Model Formulation:

The groundwater flow equation based on Darcy's Law usually describes the movement of groundwater in a porous medium such as aquifers. It is known in mathematics as the diffusion equation. It is based on the following equations:

Conservation of mass:

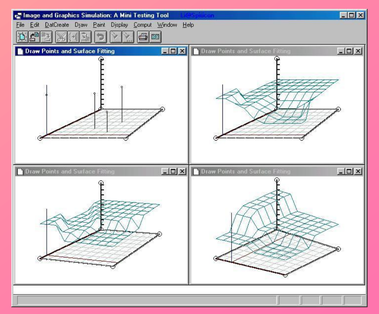
$$\frac{\Delta M_{stor}}{\Delta t} = \frac{M_{in}}{\Delta t} - \frac{M_{out}}{\Delta t} - \frac{M_{gen}}{\Delta t}$$

Differential form:

$$\frac{\partial h}{\partial t} = \alpha \left[\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} \right] - G$$

Approach to solve those equations

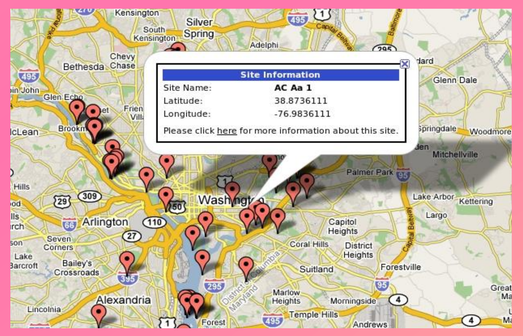
Discrete surface reconstruction :



RESULTS

Data Preparation

A web-based application for geographically plotting the water quality data in the District of Columbia was developed:



Real Data Processing and Application

These results use an algorithm to fit the initial data set using an individualized fit. This algorithm is also made by the rough graduate varied surface fitting by scanning through the fitting array. There are many clear boundary lines in the images. In order to reduce error, our new algorithm will use more accurate formulas to calculate the derivatives.

Northern VA Groundwater distribution calculated by gradually varied surfaces date from 04/01/07. The intensity indicated the depth of the groundwater:

(a) day 1

(b) day 50

(c) day 100

Northern VA Groundwater distribution calculated by gradually varied surfaces and the flow equation:

(a)day1

(b) day 2

(c) enhanced difference

(d) Day 2 with flow equation iteration

(d) Day 3 with flow equation iteration

DISCUSSION

The proposed application deals specifically with water quality data in the metropolitan Washington, D.C. area, as reported by the U.S. Geological Survey (USGS). Interested individuals will access the web-based utility and, from there, easily navigate to the desired information. The data is presented initially by icons, representing water quality testing locations, plotted onto a map of the metropolitan Washington, D.C. region; as the user clicks an icon, he or she will be presented with a list of dates, with each date corresponding to an actual water quality test. By clicking on a date, users will then be presented with a page-by-page view of the values for each type of test performed at that time (e.g. lead, arsenic, etc.). In addition to the ability to browse these sites randomly, users may enter an address, and a radius, to find only the sites of closest geographical interest.

TAKE HOME MESSAGE

The results show the usefulness of the proposed method for managing ground water quality assessment in the District of Columbia.

Further research to ensure the accuracy of the calculation is required and we will add the finite element method to this project. We also want to use MODEFLOW to calculate local and small-region flow and to use gradual variation to compute regional or global data.

ACKNOWLEDGEMENTS

The author expresses thanks to the DC Water Resources Research Institute for financial assistance and Mr. Travis Branham, a CS student at UDC, prepared the input data.

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