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A novel Approach of Groundwater Vulnerability Assessment: Backward location and Travel Time Probability Models

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ABSTRACT

The backward probability model is developed to assess the groundwater vulnerability at a pumping well. This mathematical method that can be used to determine the former location of contamination in an aquifer is derived from the advection-dispersion equation(ADE) of resident concentration by using the adjoint method. The complete adjoint equation is in the form of backward-in-time advection-dispersion equation. The appropriate choice of variables in sensitivity analysis relates the adjoint state to backward location or travel time probability of solute parcel.

The adjoint equation for location probability shows the backward location probability defining the probability that a parcel was at some other location from where it is now at some time in the past. Backward travel time probability is defined as the probability of time taken for a parcel detected at somewhere down gradient of a source point travel back to the source point where the parcel was located in the past.

For verification of probability density functions(pdfs) from the adjoint backward equation they are compared with the pdfs from the forward equation. Both forward and backward models were simulated on the hypothetical homogeneous aquifer with the size of 128mx128mx32m. Boundary conditions and aquifer property values are given in Table 1. Locations of a pumping well and observation/injection points in the domain are shown in Figure 1.

Table 1. Properties used in the simulation

Porosity		0.3	Infiltration rate [m/year]	0.432
Hydraulic conductivity [m/day]	K_{xx}, K_{yy}	86.4	Extraction rate [m^3/year]	300
	K_{zz}	8.64		
Dispersivity [m^2/day]	longitudinal	5.0	Specified head at x=0 [m]	32
	transverse	0.5		

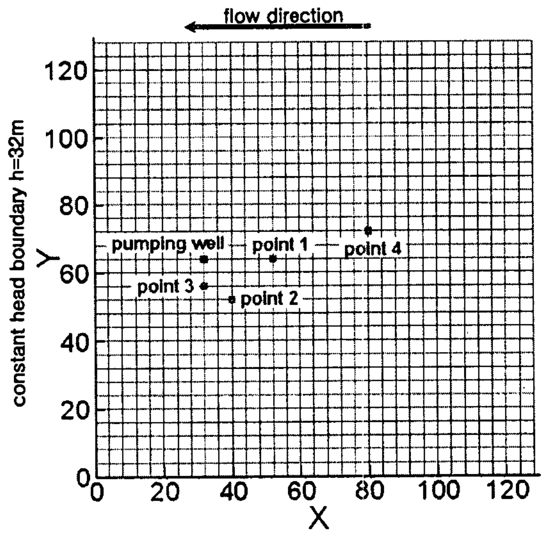

Figure 1. Top view of the hypothetical aquifer domain

In forward simulation, solute was injected at each point from 1 to 4, one at a time and the concentration breakthrough curves were observed at the pumping well. In backward simulation, it is assumed that the solute was observed at the pumping well and the transport was simulated backward in time. The concentration was observed at each of the point 1 to 4. The results show that the pdfs from both forward and backward equations fit each other well (Figure 2). The correlation coefficient ranges from 0.96 to 0.99 proving that the backward equation follows the physical process of the forward equation.

The adjoint backward location and travel time probability model will be applied in the field site located in Changwon, Korea to assess the vulnerability of groundwater to contaminants and guarantee the quality of water from the pumping well.

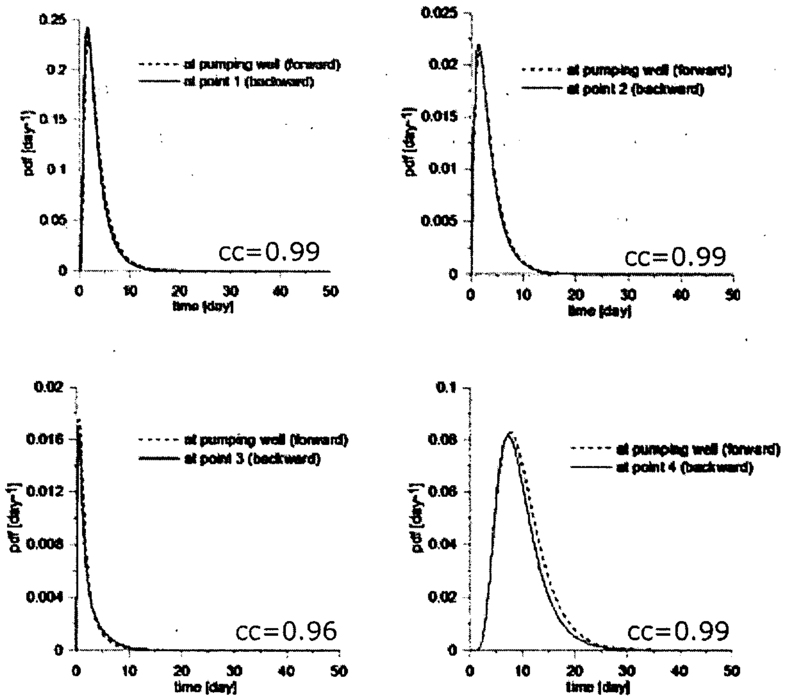

Figure 2. Travel time pdfs from both the backward and forward simulations.

The backward probability model can be used to predict the impact of contamination event to a well physically based on the process of contaminant transport. With the backward probability model one can have the information about the travel time and location of the contaminant discharged at any point in the field site to the pumping well. This gives the computational advantage. From the result of the backward probability model one can be informed about the location of high risk or the acceptable quantity of contaminant discharge of the site. This information can help to set criteria to protect the quality of water extracted from a pumping well by assessing the vulnerability of groundwater at the pumping well.

Key words: groundwater vulnerability, backward location probability, backward travel time probability.

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