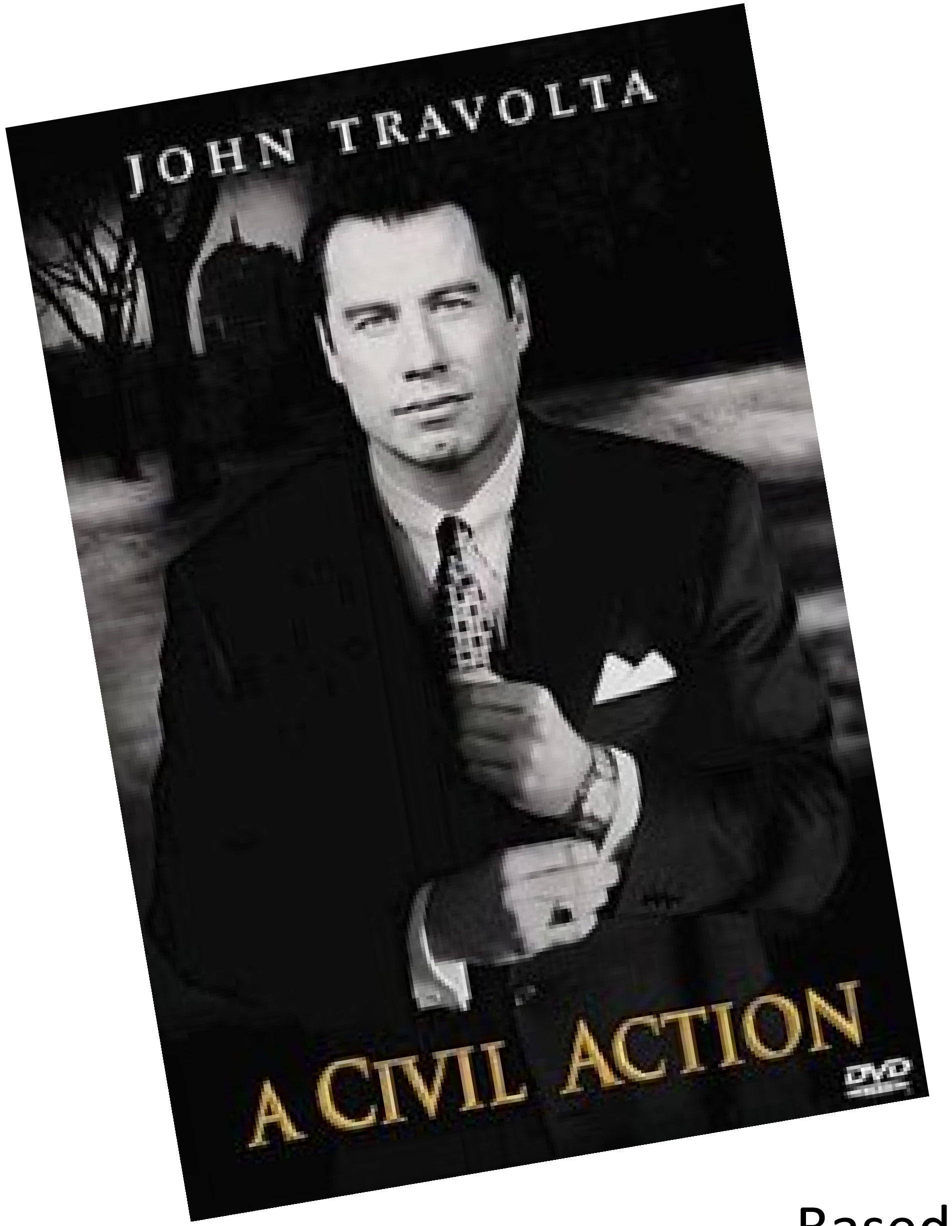
Contaminant Transport

Today’s agenda

- Wrap up contaminant/solute transport
- Groundwater modeling with solute transport

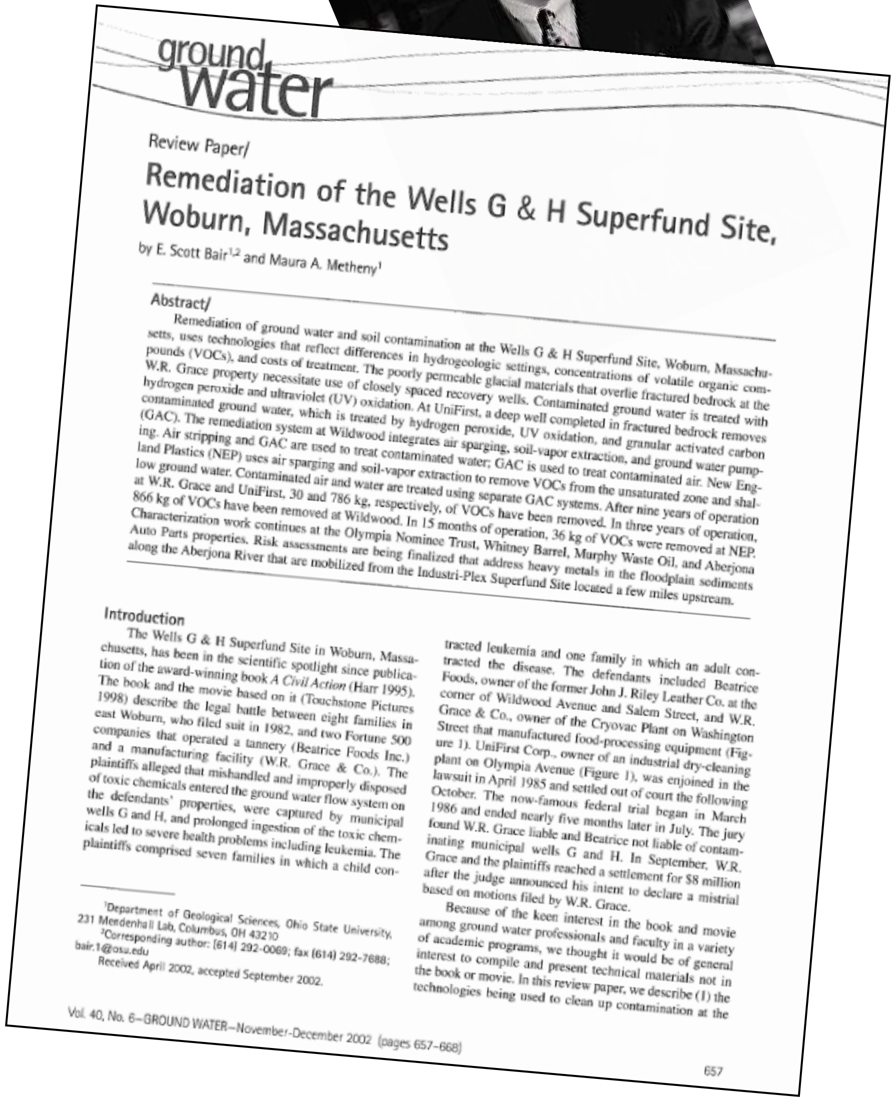


Based on book by Jonathan Harr
Based on true story

Anderson v. Cryovac

In 1982 eight families filed suit against Beatrice Food Company and W.R. Grace.

The allegation was of inappropriately disposed toxic chemicals polluting the town's water supply (wells G and H)



ground water

Review Paper/

Remediation of the Wells G & H Superfund Site, Woburn, Massachusetts

by E. Scott Bair[1,2] and Maura A. Metheny[1]

Abstract/

Remediation of ground water and soil contamination at the Wells G & H Superfund Site, Woburn, Massachusetts, uses technologies that reflect differences in hydrogeologic settings, concentrations of volatile organic compounds (VOCs), and costs of treatment. The poorly permeable glacial materials that overlie fractured bedrock at the W.R. Grace property necessitate use of closely spaced recovery wells. Contaminated ground water is treated with hydrogen peroxide and ultraviolet (UV) oxidation. At UniFirst, a deep well completed in fractured bedrock removes contaminated ground water, which is treated by hydrogen peroxide, UV oxidation, and granular activated carbon (GAC). The remediation system at Wildwood integrates air sparging, soil-vapor extraction, and ground water pumping. Air stripping and GAC are used to treat contaminated water; GAC is used to treat contaminated air. New England Plastics (NEP) uses air sparging and soil-vapor extraction to remove VOCs from the unsaturated zone and shallow ground water. Contaminated air and water are treated using separate GAC systems. After nine years of operation at W.R. Grace and UniFirst, 30 and 786 kg, respectively, of VOCs have been removed. In three years of operation, 866 kg of VOCs have been removed at Wildwood. In 15 months of operation, 36 kg of VOCs were removed at NEP. Characterization work continues at the Olympia Nominee Trust, Whitney Barrel, Murphy Waste Oil, and Aberjona Auto Parts properties. Risk assessments are being finalized that address heavy metals in the floodplain sediments along the Aberjona River that are mobilized from the Industri-Plex Superfund Site located a few miles upstream.

Introduction

The Wells G & H Superfund Site in Woburn, Massachusetts, has been in the scientific spotlight since publication of the award-winning book *A Civil Action* (Harr 1995). The book and the movie based on it (Touchstone Pictures 1998) describe the legal battle between eight families in east Woburn, who filed suit in 1982, and two Fortune 500 companies that operated a tannery (Beatrice Foods Inc.) and a manufacturing facility (W.R. Grace & Co.). The plaintiffs alleged that mishandled and improperly disposed of toxic chemicals entered the ground water flow system on the defendants' properties, were captured by municipal wells G and H, and prolonged ingestion of the toxic chemicals led to severe health problems including leukemia. The plaintiffs comprised seven families in which a child contracted leukemia and one family in which an adult contracted the disease. The defendants included Beatrice Foods, owner of the former John J. Riley Leather Co. at the corner of Wildwood Avenue and Salem Street, and W.R. Grace & Co., owner of the Cryovac Plant on Washington Street that manufactured food-processing equipment (Figure 1). UniFirst Corp., owner of an industrial dry-cleaning plant on Olympia Avenue (Figure 1), was enjoined in the lawsuit in April 1985 and settled out of court the following October. The now-famous federal trial began in March 1986 and ended nearly five months later in July. The jury found W.R. Grace liable and Beatrice not liable of contaminating municipal wells G and H. In September, W.R. Grace and the plaintiffs reached a settlement for $8 million after the judge announced his intent to declare a mistrial based on motions filed by W.R. Grace.

Because of the keen interest in the book and movie among ground water professionals and faculty in a variety of academic programs, we thought it would be of general interest to compile and present technical materials not in the book or movie. In this review paper, we describe (1) the technologies being used to clean up contamination at the

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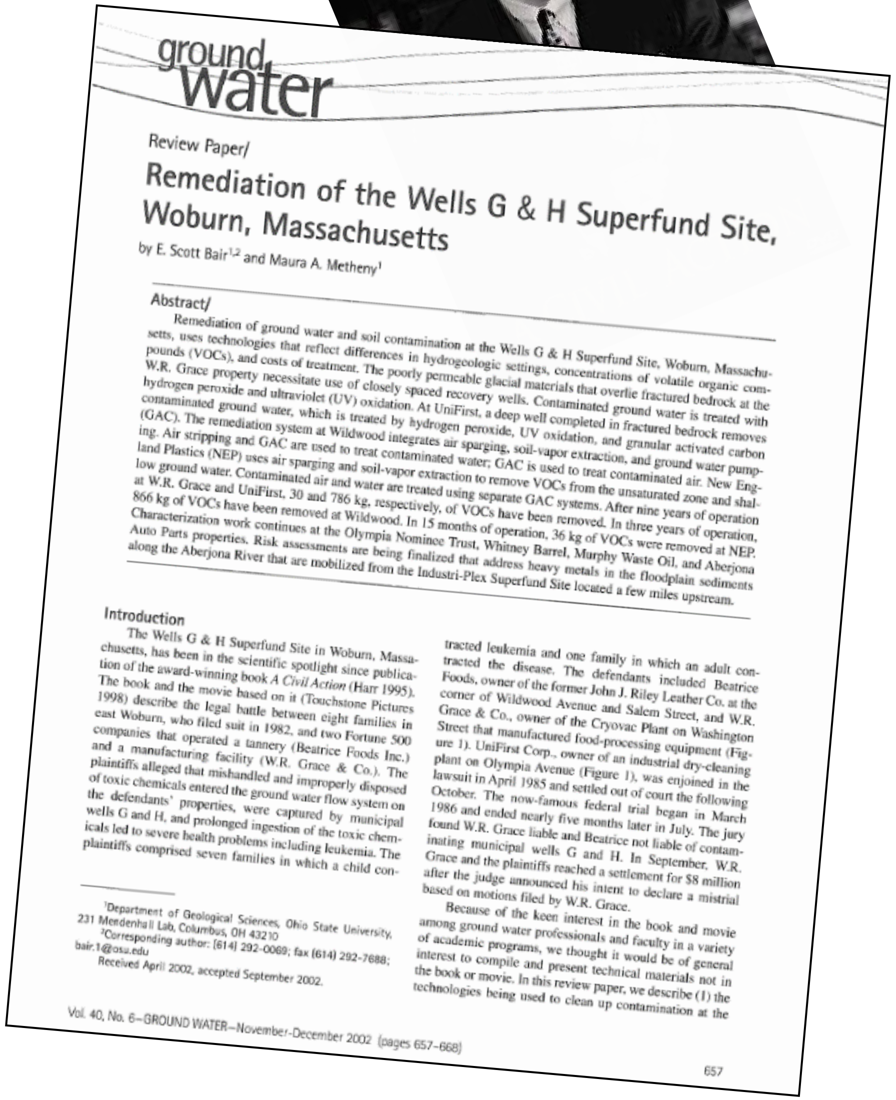
Anderson v. Cryovac

Of the 8 families, 7 had children who had contracted leukemia, and 1 family with an adult contracted the disease.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Where is Woburn?

Who were the defendants?

Beatrice

Selected products owned (at various times) by Beatrice Food Company

GRACE

Enriching Lives, Everywhere.™

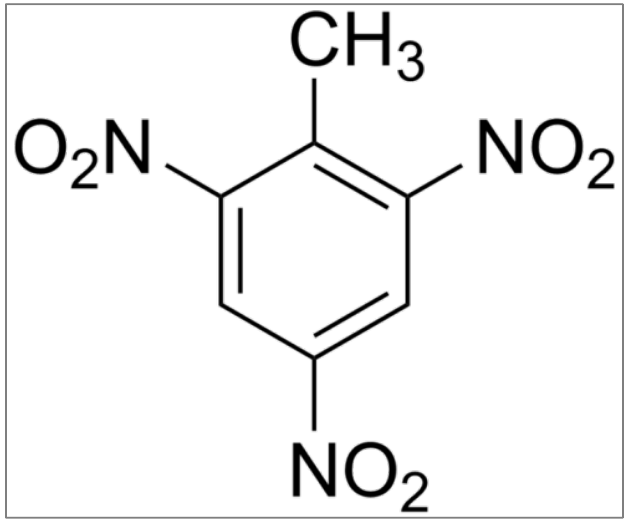
Linked to both trichloroethylene (TCE) spills and 270,000 asbestos-related lawsuits.

Filed for bankruptcy in 2001 (after allegedly transferring $4-5 billion to daughter companies)

Woburn Massachusetts… Some history

From 1853 – 1931 companies produced:

- Arsenic-based insecticides
- Sulfuric acid
- TNT
- Chemicals for the leather industry

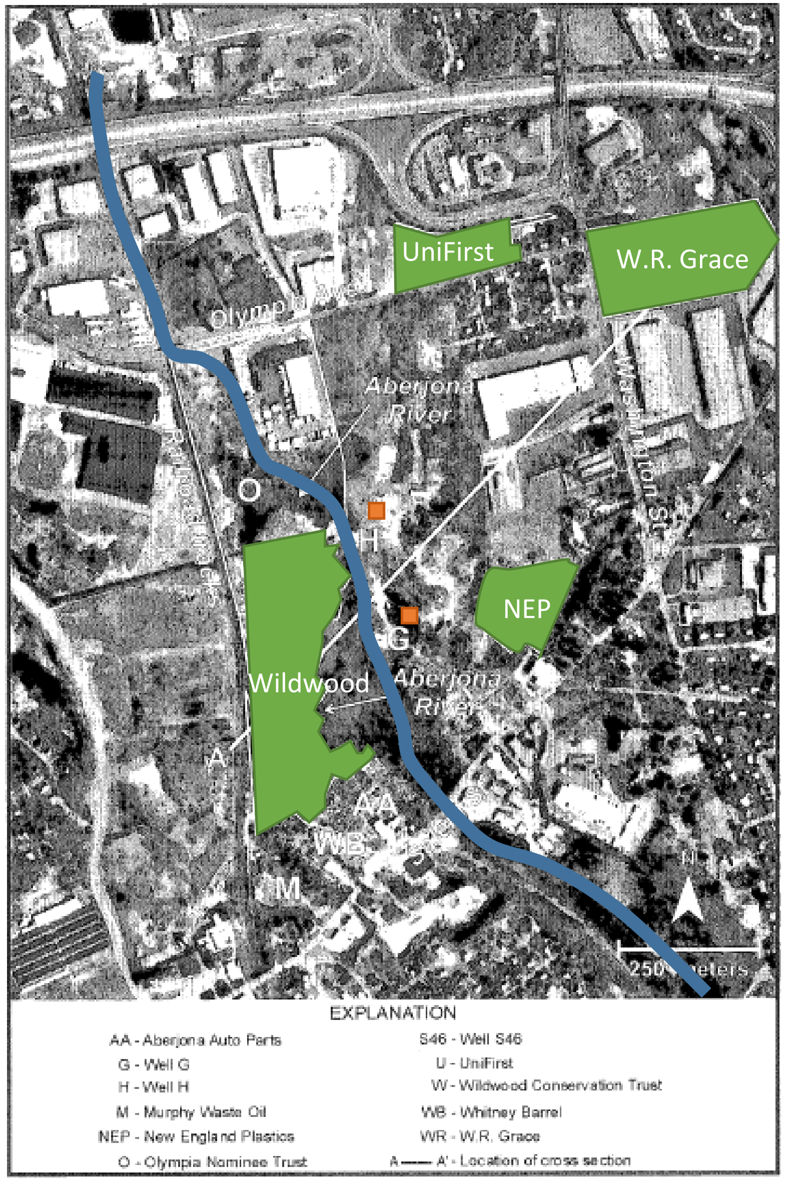


Outcome of the court case

In 1991, after several **studies,**
it was ruled that:

- Wildwood Conservation Corp (purchased Riley tannery)
- UniFirst
- W.R. Grace
- New England Plastics

Had to pay $70 million for clean up costs (which are ongoing)



The ‘long tail’ wags again

Selected figures from Bair and Metheny (2002)

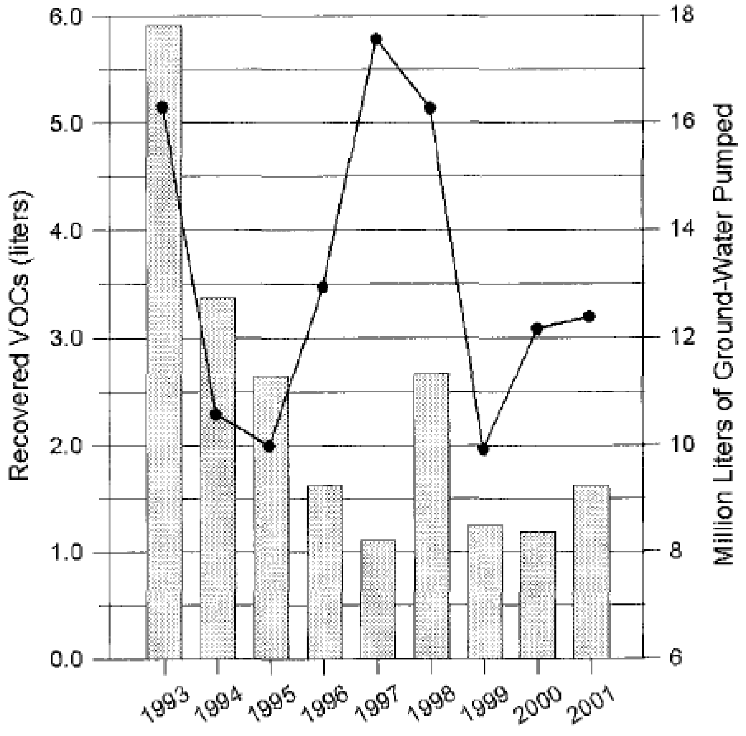


Figure 4. Recovered VOCs (bars) versus pumpage (solid line) at W.R. Grace from October 1992 to September 2001.

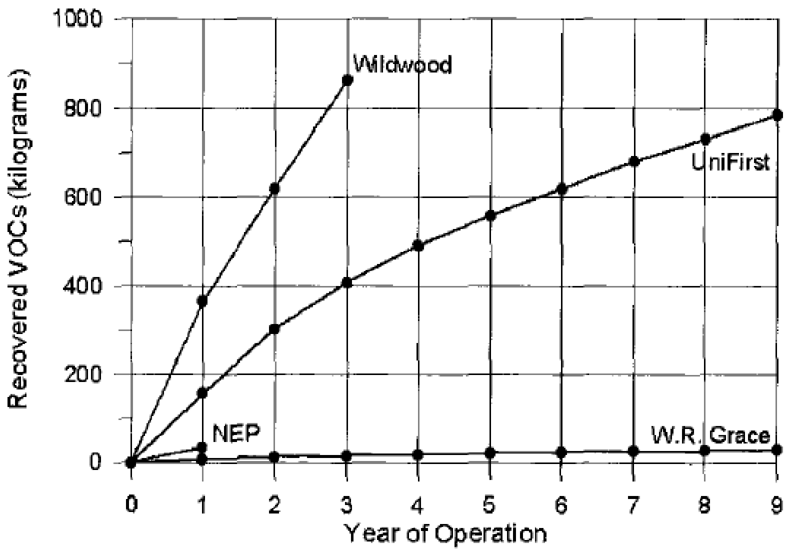


Figure 10. Cumulative recovered mass of VOCs at the Wells G & H Superfund Site by responsible party.

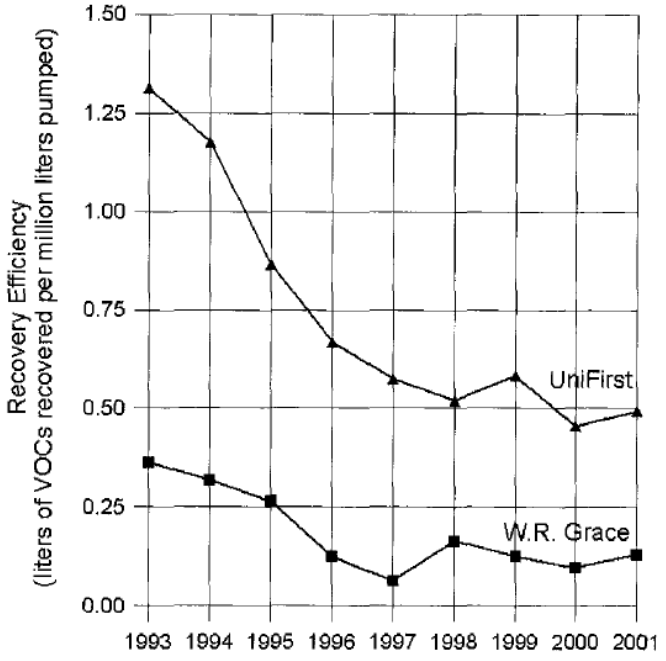
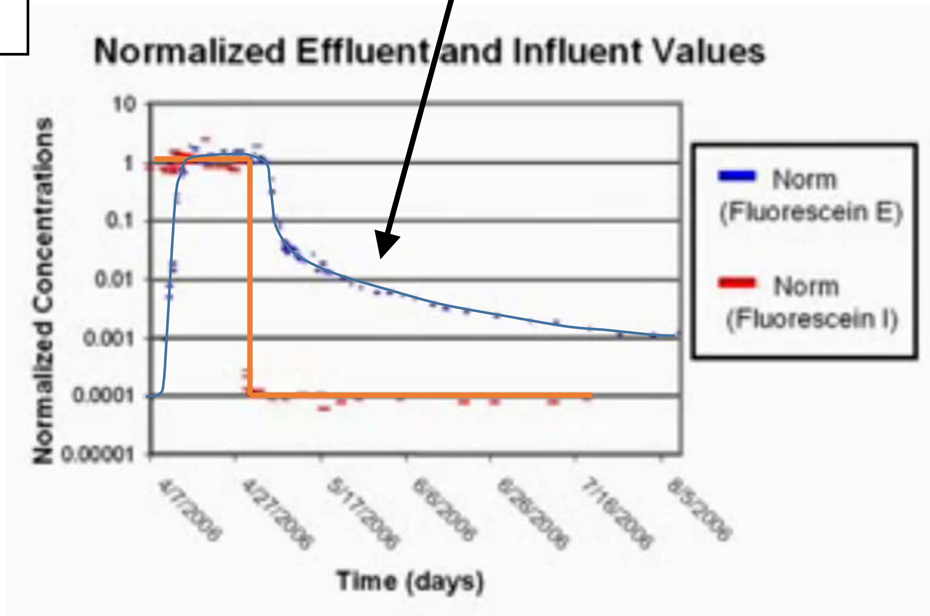


Figure 11. Efficiency of remediation systems at W.R. Grace and UniFirst during first nine years of operation.

Remember...

Influence of dispersion



When simulating solute transport…

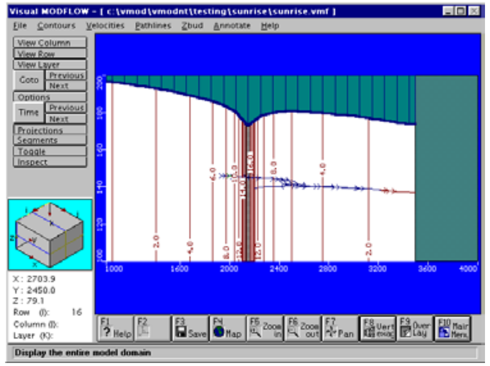
Bare bones basics of modeling

Groundwater modeling software (e.g. MODFLOW, FEFLOW, Hydrus, etc.) solve equations relating to flow (and sometimes transport too)

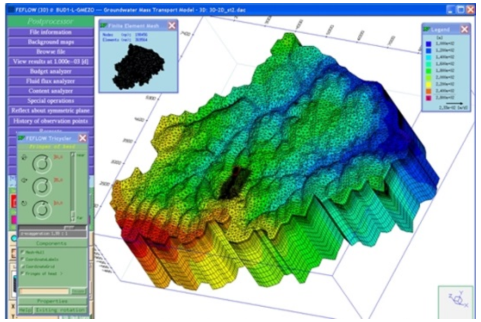
Basically we 'discretize' space and time, and calculations are made for each grid cell and timestep

We can (try to) predict potential behavior (influence of pumping, fate of a pollutant spill)

Screenshot from Visual MODFLOW



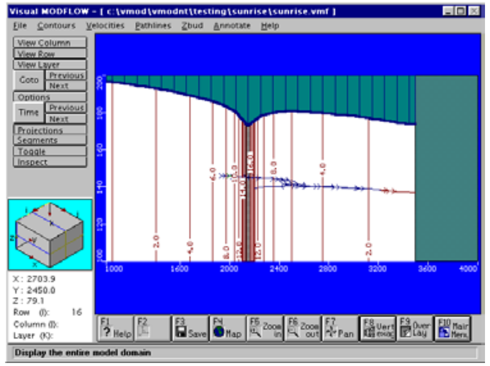
Screenshot from FEFLOW



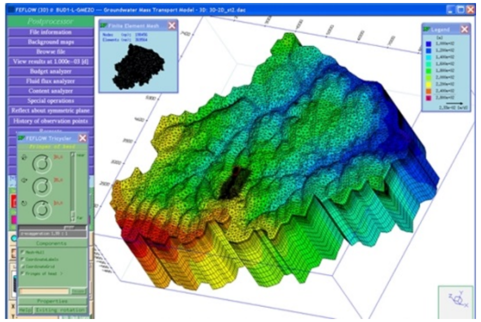
Why use a groundwater model?

It is important to remember...

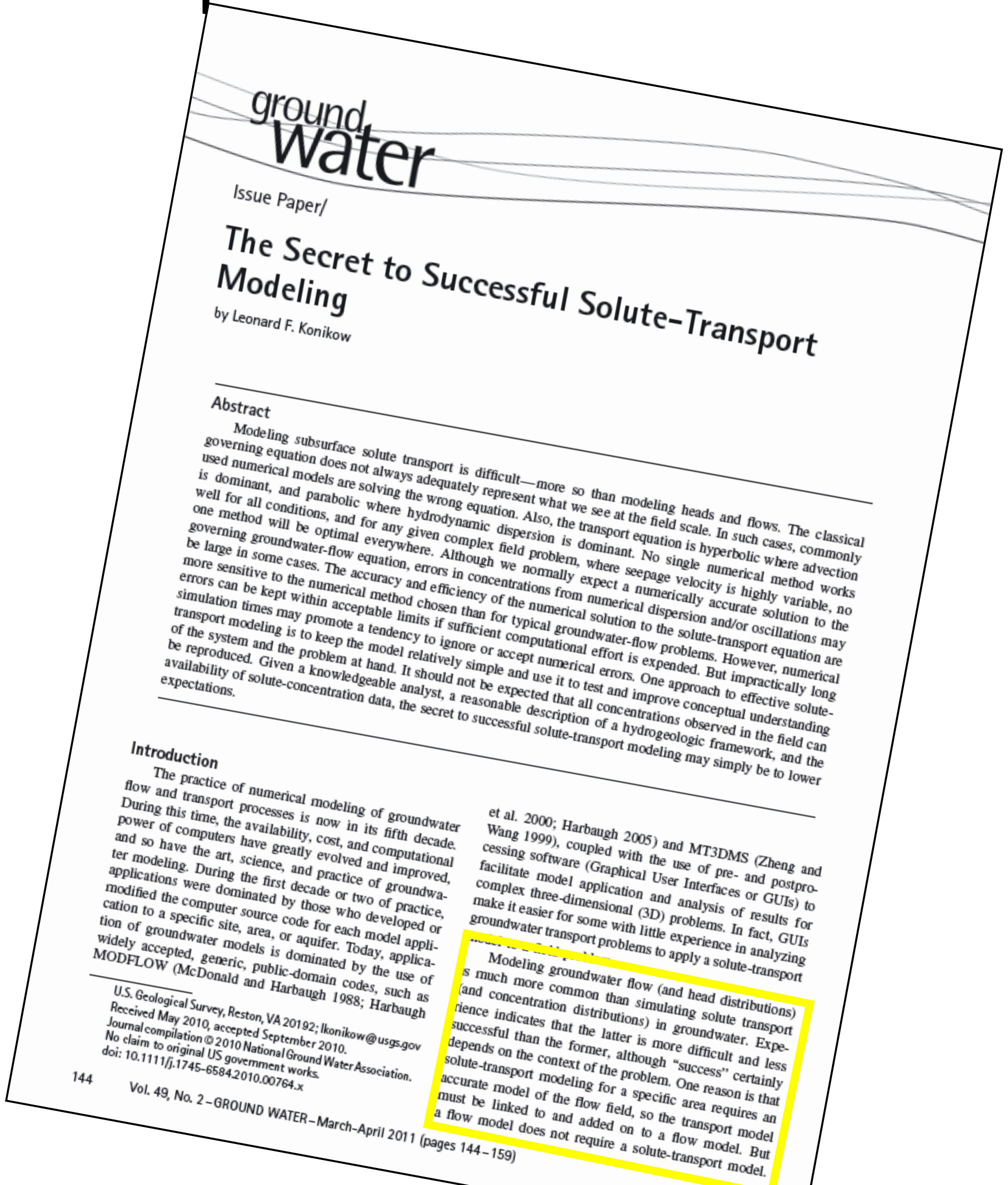
Screenshot from Visual MODFLOW



Screenshot from FEFLOW



Using models to predict solute transport



groundwater

Issue Paper/

The Secret to Successful Solute-Transport Modeling

by Leonard F. Konikow

Abstract

Modeling subsurface solute transport is difficult—more so than modeling heads and flows. The classical governing equation does not always adequately represent what we see at the field scale. In such cases, commonly used numerical models are solving the wrong equation. Also, the transport equation is hyperbolic where advection is dominant, and parabolic where hydrodynamic dispersion is dominant. No single numerical method works well for all conditions, and for any given complex field problem, where seepage velocity is highly variable, no one method will be optimal everywhere. Although we normally expect a numerically accurate solution to the governing groundwater-flow equation, errors in concentrations from numerical dispersion and/or oscillations may be large in some cases. The accuracy and efficiency of the numerical solution to the solute-transport equation are more sensitive to the numerical method chosen than for typical groundwater-flow problems. However, numerical errors can be kept within acceptable limits if sufficient computational effort is expended. But impractically long simulation times may promote a tendency to ignore or accept numerical errors. One approach to effective solute-transport modeling is to keep the model relatively simple and use it to test and improve conceptual understanding of the system and the problem at hand. It should not be expected that all concentrations observed in the field can be reproduced. Given a knowledgeable analyst, a reasonable description of a hydrogeologic framework, and the availability of solute-concentration data, the secret to successful solute-transport modeling may simply be to lower expectations.

Introduction

The practice of numerical modeling of groundwater flow and transport processes is now in its fifth decade. During this time, the availability, cost, and computational power of computers have greatly evolved and improved, and so have the art, science, and practice of groundwater modeling. During the first decade or two of practice, applications were dominated by those who developed or modified the computer source code for each model application to a specific site, area, or aquifer. Today, application of groundwater models is dominated by the use of widely accepted, generic, public-domain codes, such as MODFLOW (McDonald and Harbaugh 1988; Harbaugh et al. 2000; Harbaugh 2005) and MT3DMS (Zheng and Wang 1999), coupled with the use of pre- and postprocessing software (Graphical User Interfaces or GUIs) to facilitate model application and analysis of results for complex three-dimensional (3D) problems. In fact, GUIs make it easier for some with little experience in analyzing groundwater transport problems to apply a solute-transport

Modeling groundwater flow (and head distributions) s much more common than simulating solute transport (and concentration distributions) in groundwater. Experience indicates that the latter is more difficult and less successful than the former, although "success" certainly depends on the context of the problem. One reason is that solute-transport modeling for a specific area requires an accurate model of the flow field, so the transport model must be linked to and added on to a flow model. But a flow model does not require a solute-transport model.

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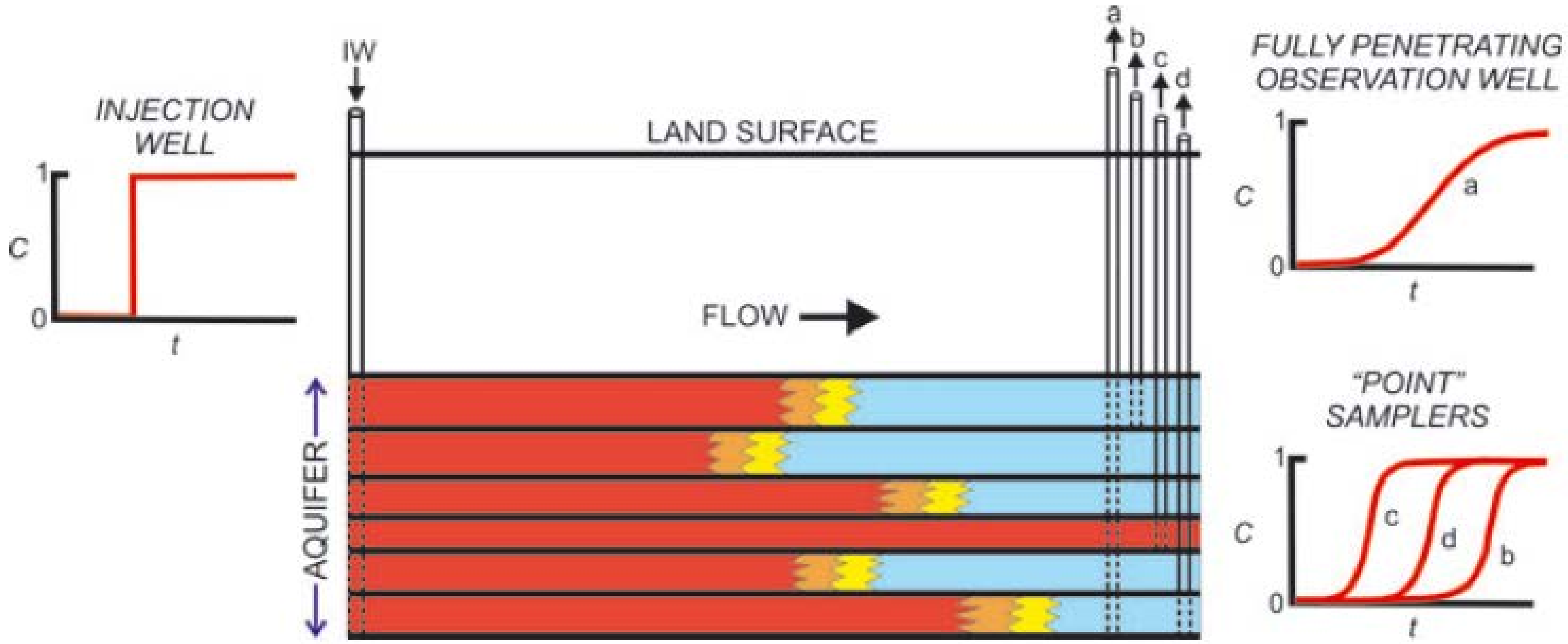
Do we know what we are measuring?

Typically, when a model is being set up, we test to see whether it can reproduce field measurements (e.g. heads, or concentrations). This is called **model calibration**

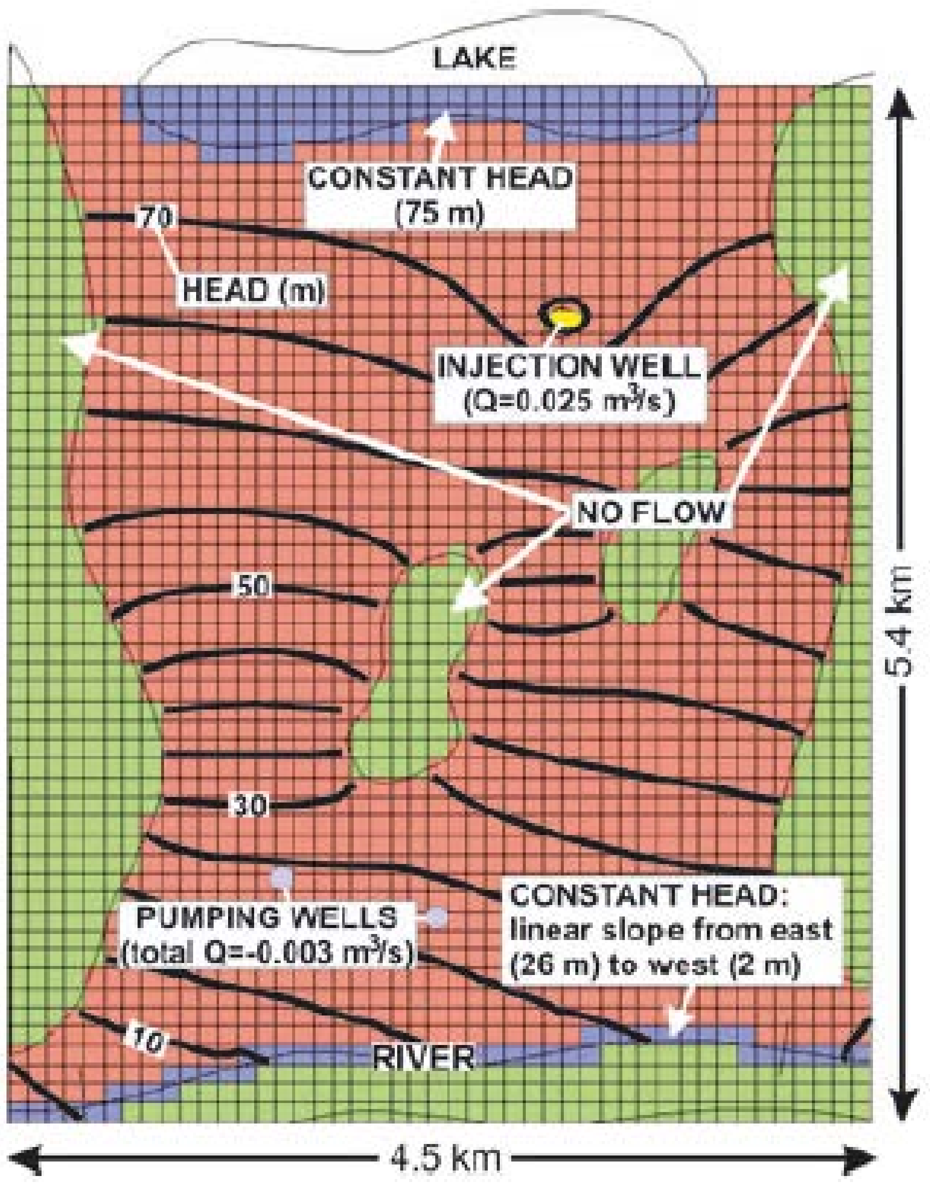


Test case

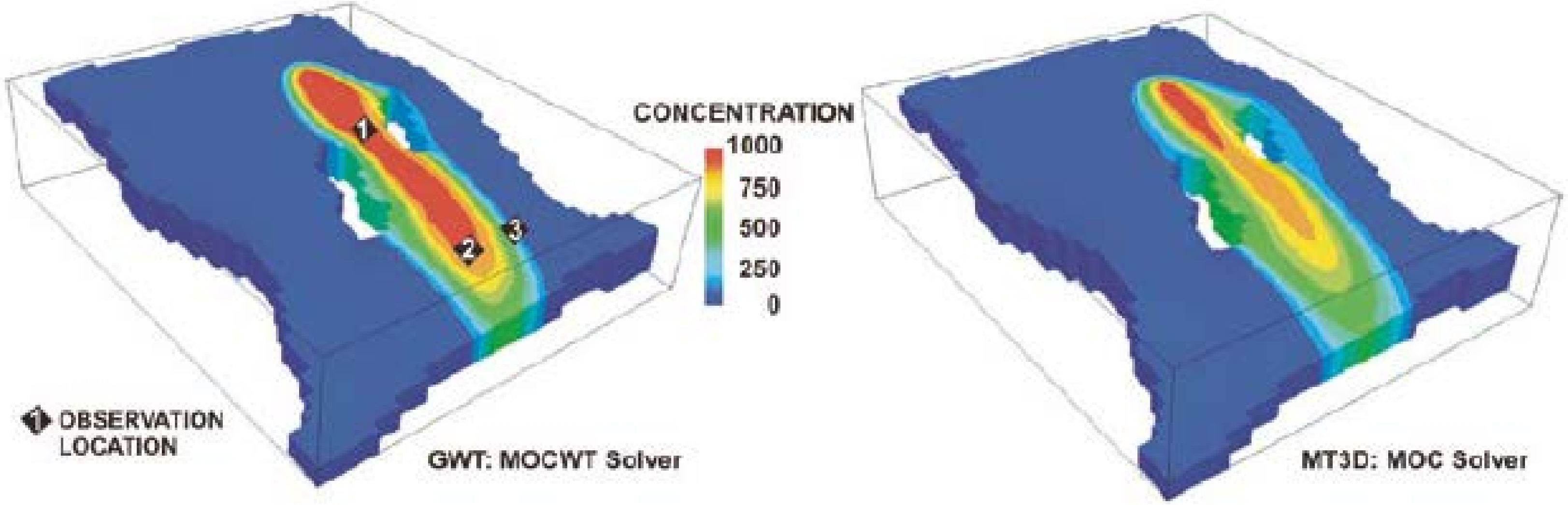
The benefits of a model to explore processes... We can set up a case where everything is known.

In this example:

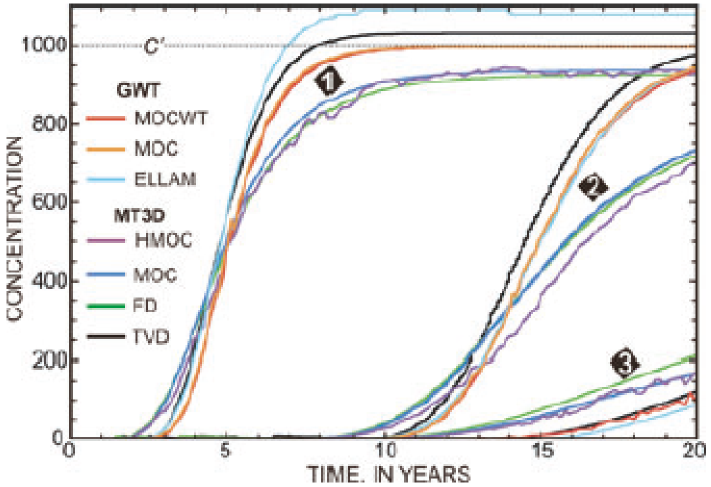
- Constant head (e.g. water bodies)
- No flow (e.g. low K regions)
- Aquifer
- Constant head lines
- Pollution source



Which mathematical approach to solve equations?



Be aware of what solver you are using



How to represent heterogeneity

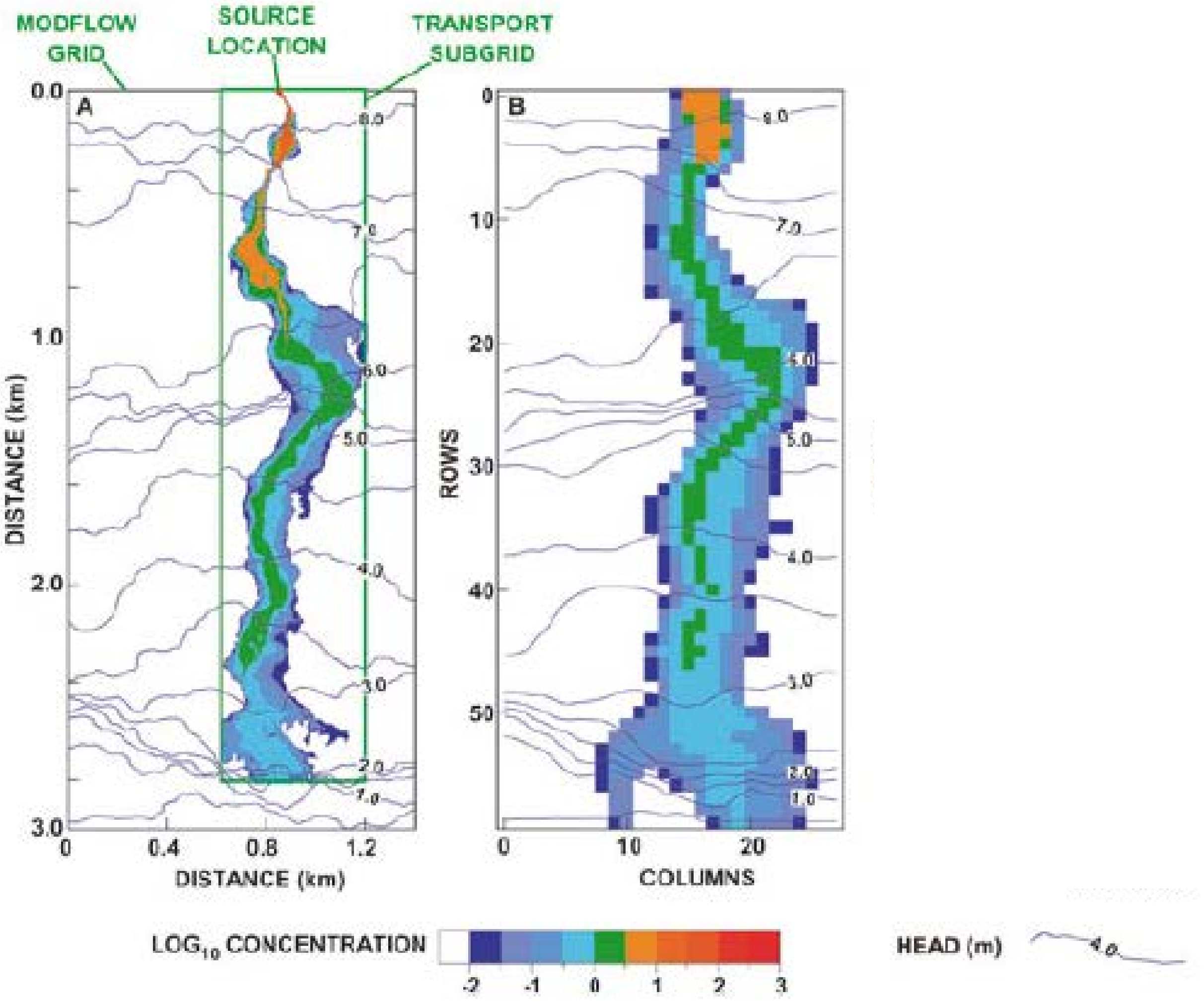


Figure 8. Effect of scale of discretization and resolution of heterogeneity on calculated heads and concentrations for case of hypothetical contaminant release from a leaky borehole in a regional aquifer: (A) grid spacing = 2 m; (B) grid spacing = 50 m; and (C) *T* defined on 50-m spacing from B, but numerical solution obtained using grid spacing = 2 m.

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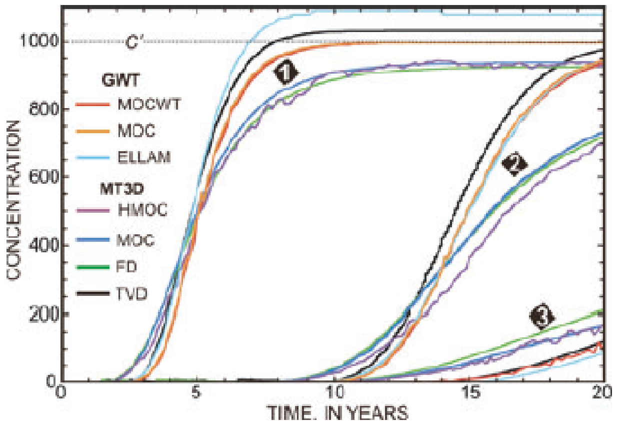

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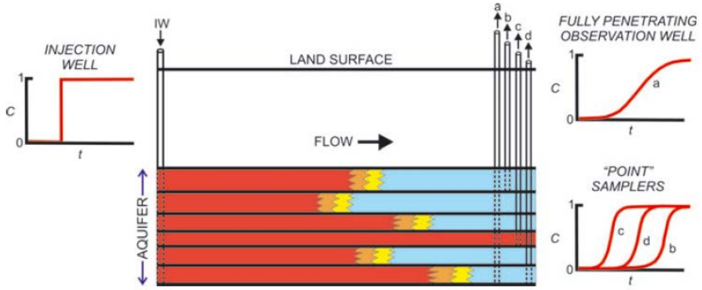

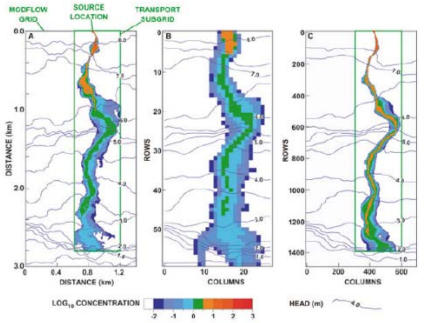

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