



A One-Day Seminar For
Decision Makers & Managers

The Modeling Management Course

Groundwater Modeling Management And Application for Decision Making

Sources of Uncertainty in Groundwater Modeling:
Identification, Calculation & Management

Tuesday March 14, 2006

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*Hosted at: Stony Brook University (SUNY)
Stony Brook, NY*

Presented by



Course Supporters



Groundwater Modeling Management and Application for Decision Making

Hosted at Stony Brook University (SUNY)
March 14, 2006, Long Island, NY

Introduction

The use of models for environmental management and remediation decision-making is commonplace. Despite the importance of these decisions, the considerable expense associated with model construction, and the intense stakeholder scrutiny to which most models are subject, rarely is the question asked by those who build or use models: *how wrong could this model be?* In fact most models are under-performers. This is because many of the assumptions that underlie the model are never tested for reasonableness – and because most models are subject to relatively ineffective calibration procedures that fail to extract as much information from calibration data as that which the data contains. Ad hoc sensitivity analyses, which typify most modeling applications, often demonstrate little more than that those who build models are aware of their shortcomings, but are unable to properly quantify these shortcomings or manage the uncertainty of model outputs.

One of the reasons why robust assessment of model error has been lacking in the past is that, until recently, methodologies and software to complete such analyses were unavailable. But there are other reasons as well – such as the lack of training in the calibration of models and in the analysis of the uncertainty of their outputs. Another reason, unfortunately, is that it is often not in the interests of those who develop models, and of those who use models for management and regulatory purposes, to showcase their shortcomings. However the time is fast approaching when the environmental community will tolerate this no longer.

Modern methodologies and software, such as recent versions of the PEST parameter estimation package, take model calibration and predictive error analysis into a new era. Model calibration is effected using advanced mathematical regularization techniques, often with efficiencies commensurate with traditional calibration methodologies based on lumped-parameter inversion. These advanced methods capture far more information from the calibration data than traditional methods, and are complimented by new methodologies for quantification of model predictive uncertainty. Modern uncertainty analysis recognizes the dominant contribution made to potential model error by hydrogeological complexity that is invariably present within a simulated groundwater system, but is beyond the ability of the calibration process to capture, a contribution mostly ignored by traditional approaches.

The ability to quantify model predictive uncertainty brings with it the ability to quantify, and hence optimize, the effect of data acquisition in reducing that uncertainty. This is indeed a powerful tool because it provides a sound scientific basis for optimization of effort and expense in acquiring new data to support future modeling and management activity. The contributions made by different parameter classes, or hydraulic property types, to potential model error can also be calculated, as can the irreducible model error – that error which no amount of future field or laboratory data acquisition can ever remove. Recently developed software allows relatively inexpensive investigations into these issues to be undertaken before a model is even calibrated; thus the expected uncertainty associated with a model's predictions, given the data available for its calibration, can be assessed before funds are committed to its further construction.

The seminar consists of a series of lectures in which sources of error in groundwater modeling are fully discussed. Concepts are explained in full, clearly and completely, with many examples from real-world models. Though the methodologies discussed in the seminar have firm mathematical foundations, lectures focus on concepts rather than equations. For those who are interested in pursuing the topics further, a CD is provided with PEST, its utility software, and supporting documentation. Ample time is provided for questions and discussion.

Who Should Attend

The seminar is aimed at a broad spectrum of attendees, primarily decision-makers and managers. It is NOT a model construction or calibration course. It is an opportunity to explain to those with a broad range of skills and experience why models are wrong, how wrong they can be, and how this potential wrongness can be calculated and managed to make better, more defensible decisions. However, even experienced modelers will add to their skill base and become aware of new tools available to them to assist them with their work. Decision-makers, managers and regulators will increase their understanding of what they can expect from models and those who build them, and learn to ask the right questions (and better avoid being fooled with the wrong answers). They will also learn how better modeling RFPs should result in better modeling. Attorneys will become better informed of the strengths and weakness of modeling as a means of environmental investigation.

The Program

The program is divided into 6 sessions – 4 short sessions in the morning and 2 longer sessions in the afternoon. Morning sessions introduce attendees to the role that models play in decision making past, present and future, using a variety of examples, and then outline the role that basic regression methods have classically played in model evaluation, calibration and deployment. Afternoon sessions focus on causes of model predictive error and the ways in which the extent of these errors can be quantified in most modeling contexts. The sessions are presented in a semi-informal manner, and plenty of time is allotted for questions and discussion. Further discussion is encouraged at the evening reception where all presenters will be present and available for questions.

Course Outline

Registration: 7:45 am – 8:45 am

Introduction: 8:45 am – 9:00 am

9:00 am – 9:15 am - The Role of Models in Decision Support

- Important issues facing decision makers
- Important predictions made with models
- Possible consequences of erroneous predictions

9:15 am – 9:45 am - The Modeling Process, Past and Current

- Philosophical basis for models
- Requirements for model applications
- Uncertainty (*Why?*)

9:45 am – 10:15 am – Assumptions and Limitations

- Fate and transport parameters
- Choices in model selection

10:15 am – 11:30 am – Examples

- Reporting modeling work
- Sufficiency of site characterization data
- Simple model application at a LUST site
- Uncertainty in numerical models

11:30 am – 12:00 pm – The Modeling Deliverable

- How are modeling results delivered
- What the deliverable actually delivers

Lunch: Catered On-Site and Included with Seminar Fee

1:00 pm – 2:00 pm - Model Calibration

- Basic statistics, calibration and available software
- Measurement error and structural error
- Geologist's wisdom as parameter constraints
- Statistics and other calibration metrics
- Spatial parameter definition
- Hypothesis-testing through calibration
- The role of Bayes theorem

2:15 pm – 3:15 pm - The Cost of Uniqueness

- Regularization – what it means
- Mathematical regularization and examples
- The calibrated parameter and its real-world equivalent
- The calibration null space and why it is important
- Where did all the detail go - the cost of uniqueness

3:30 pm – 5:00 pm - Model Predictive Uncertainty Analysis

- Classical and calibration-constrained Monte-carlo analysis
- Predictive calibration
- Contributors to uncertainty and their quantification
- Optimization of data acquisition with examples
- Nonlinear uncertainty analysis with example

Presenters

Dr. John Doherty - Dr. John Doherty has worked in the groundwater industry for nearly 30 years, first as an exploration geophysicist and then as a modeler. He has worked in the public, private and university sectors, and today runs his own company which undertakes modeling and data processing in many different environmental contexts. John is best known as the developer of the model-independent parameter estimation and uncertainty analysis program, PEST. He currently works as an independent consultant, and with the University of Queensland where, together with his students, he researches and develops calibration and predictive uncertainty analysis methods. John has developed models to support decisions in groundwater remediation, mining applications, surface water TMDLs and many other contexts. He is an invited speaker and instructor worldwide and provides training in modeling, calibration and uncertainty analysis throughout the world. Always conscious of the uncertainties that underlie predictions made with models, John developed this seminar to outline the principal sources of uncertainty, and the variety of methods available for their assessment, for those who make decisions based on models. His lecture style is informative and entertaining. Concepts are developed logically and presented clearly. Every attempt is made to avoid boring the audience, while conveying that predictive error analysis is possible, cost effective - and often essential to defensible decision making.

Dr. Jim Weaver - Jim received his Masters and doctorate degrees in Civil Engineering from The University of Texas at Austin, and a Bachelors degree from the State University of New York, College of Environmental Science and Forestry. Dr. Weaver has worked for the U.S. Environmental Protection Agency's Office of Research and Development for 18 years; initially at the ground water research center in Ada, Oklahoma; and, since 1997, at the Ecosystems Research Division in Athens, Georgia. Dr. Weaver has worked on the development and testing of simulation models for fuel releases, evaluation of field behavior of contaminants, and oil spills. His work resulted in development of the Hydrocarbon Spill Screening Model (HSSM) for simulating impacts of fuel releases; the EPA OnSite on-line calculators for supporting site assessment; and a training course on the fate, subsurface transport and modeling of petroleum hydrocarbon contaminants.

Joe Haas - Joe has 16 years experience working as a state regulator managing a remedial section. He holds both Engineering Geologist and Hydrogeologist specialty licenses. He graduated with a B.S. in Geology from SUNY, Plattsburgh in 1988. He received a M.S. from SUNY, Stony Brook in Hydrogeology in 1997 where he researched the speciation of iron and manganese in ground water contaminated by petroleum. He has been the decision-maker and or reviewer for numerous ground water model and contaminant transport model supported projects. Joe has collaborated with various industry groups and academic institutions to provide technical assistance and training to technical and regulatory groups. Joe has also been involved in research and model development with representatives of the United States Environmental Protection Agency Office of Research and Development. His collaborative efforts have been credited as having made significant contributions to the understanding of the characteristics of MTBE in the sub-surface environment and having influenced the national debate on the use of MTBE in gasoline. The Office of Research and Development acknowledged his contributions, in 2002, in the form of an award for Exceptional Support to ORD.

Course Registration and Event Logistics

On-Line Registration

Course registration for the premier of *Groundwater Modeling Management and Application for Decision Making* will be provided by EnviroCourses.org via an on-line (internet-based) event management system. Please visit www.envirocourses.org for general information. Telephone reservations are also available by contacting Todd Margrave at EnviroCourses.org at 619-589-0784.

Course Fees

Complete course fees are \$475 for consultants and industry representatives. Qualified State and Federal Government officials will be admitted for \$375. Save \$100 by registering early (January 27, 2006 deadline.) A limited number of reduced rate academic seats (full time students and faculty) are available for \$195 each.

Lodging Accommodations

Danfords on the Sound has been chosen as the official hotel for this training event. A block of 30 rooms are reserved at the special rate of \$126 per night (plus taxes.) Nestled in the heart of Historic Port Jefferson, New York, Danfords on the Sound is ideally located at the harbors edge on Long Island Sound. The upscale inn is a mere 50 miles from New York City on the heritage North Shore of Long Island, with direct access to Ferry service to Connecticut. Directions to Danfords on the Sound are available at www.danfords.com/directions.htm. Alternate lodging is available at Holiday Inn Express Stony Brook. Please visit their website www.holidayinnexpress.com or call (631) 471-8000.

Complete lodging information is available on the official registration website www.themodelingmanagementcourse.com.

Transportation and Directions

The workshop will be conducted at Stony Brook University (*room to be determined*) Directions to the SUNY Stony Brook campus are available at <http://www.stonybrook.edu/sb/directions.shtml>. Please follow signs to the training facility and use designated parking ONLY. Attendees are responsible for all transportation including airfare, rental cars, etc. Please consult your travel agent or visit the EnviroCourses.org website for travel links and assistance.