

WHI E-News Topics

2004 April Edition

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Upcoming Professional Courses:

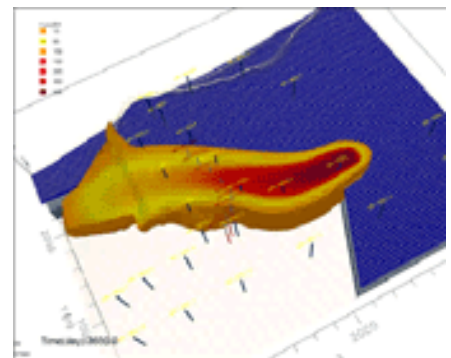
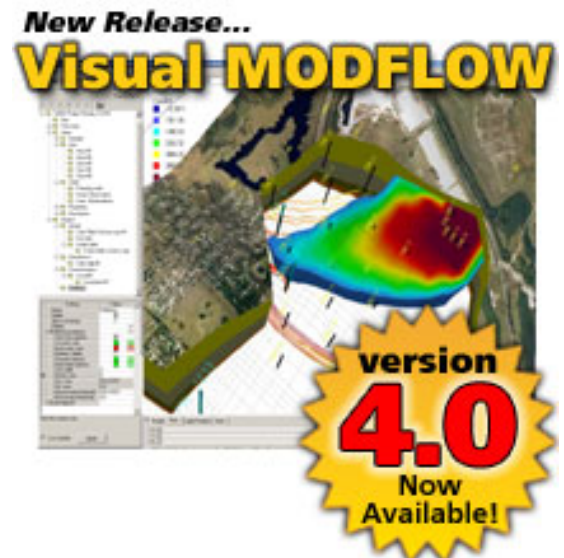
- » [Applied Groundwater Flow & Contaminant Transport Modeling](#)
- » [Contaminated Site Risk Assessment and Groundwater Modeling](#)
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- » [Aquifer Test Analysis](#)
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Tips & Tricks

- » [Using Cutting Edge Optimization Technologies With Visual MODFLOW Version 4.0](#)

Technical Highlights

Waterloo Hydrogeologic, Inc. is a recognized leader in the development and application of environmental software and services.



Call for
**Guest
Columnists!**

We want your articles! Please send your groundwater related article to us today!

Product News

Visual MODFLOW Pro 4.0 Now Available!

Visual MODFLOW Pro is the proven standard for professional 3D groundwater flow and contaminant transport modeling using MODFLOW-2000, MODPATH, MT3DMS, RT3D, WinPEST, and the VMOD 3D-Explorer. Visual MODFLOW Pro represents the most complete and powerful graphical modeling environment available.

This fully-integrated groundwater modeling allows you to:

- » Graphically design the model grid, properties, and boundary conditions;
- » Visualize the model input & output parameters in 2D or 3D;
- » Run groundwater flow, pathline, and contaminant transport simulations;
- » Automatically calibrate the model using WinPEST or manual methods; and
- » Display modeling results in high-resolution, 3D color graphics using the VMOD 3D-Explorer

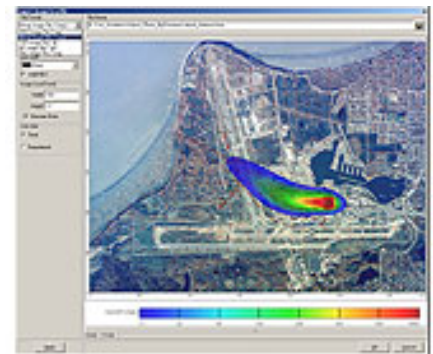
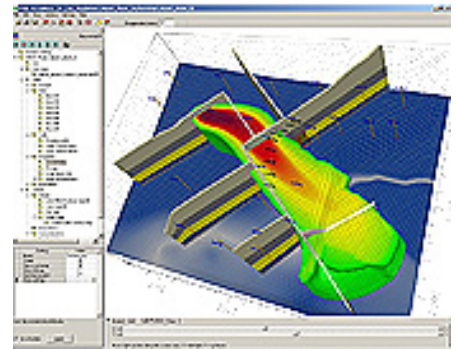
Plus additional features and improvements requested by Visual MODFLOW users including:

Supports Pumping Well Optimization - Now supports MGO, the best pumping well optimization software available! You can quickly determine the optimal well pumping and/or injection rates at one or more wells in order to achieve a specific objective while maintaining reasonable system responses.

Advanced Predictive Analysis using WinPEST! - WinPEST has been updated to include the advanced predictive analysis capabilities of PEST-ASP, helping you to minimize or maximize a specific system response (e.g. aquifer head or groundwater concentration) by adjusting selected model parameters within a given bounds, while still maintaining the obligation of a calibrated model.

Integrated SAMG Solver* - Dramatically Reduces Model Run Times! - The new SAMG Solver developed by the SCAI-Fraunhofer Institute has been demonstrated to perform 3 to 11 times faster than the traditional PCG solver for medium size models, and much faster still for large models containing 1 million or more grid cells!

Visual MODFLOW Pro now integrates Enviro-Base Pro! An all-in-one database designed to house a variety of referenced property



information used when developing groundwater models. With the ability to add and edit information, Enviro-Base Pro enables you to consolidate your technical references into one package that can be easily launched, searched and updated!

Improved Process for Importing MODFLOW Data Sets - Visual MODFLOW 4.0 has a significantly improved importing process that supports both MODFLOW-2000 Groundwater Process data sets, and older data sets from MODFLOW-96 and MODFLOW-88.

Expanded Data Import & Interpolation Capabilities - Import and interpolate distributed properties for Initial Heads, Initial Concentrations, and Dispersivities from external data sources including XYZ ASCII files (.TXT), MS Access database files (.MDB), Excel spreadsheet files (.XLS) and ESRI Point and Line Shape files (.SHP).

Enhanced Support for Importing/Exporting Images - Common image formats including .JPG, .GIF, .TIF, .PNG and .BMP can be displayed as site maps, and transparency settings may be applied to the imported images in order to display multiple images simultaneously, or to view other model attributes underneath the site map images.

Significantly Improved Tools for Designing Grid Layer Surfaces - Now you can easily digitize the desired cell area using a polygon or rectangle, or by painting a set of cells, and then assign a constant elevation to the top or bottom of the layer surface. Built-in data validation checks prevent the layer surfaces from intersecting adjacent layer surfaces.

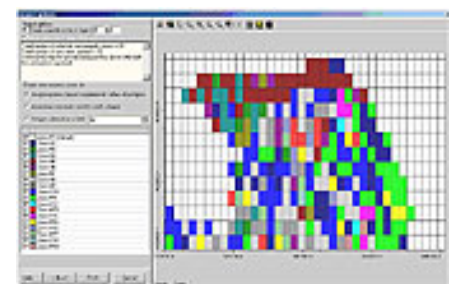
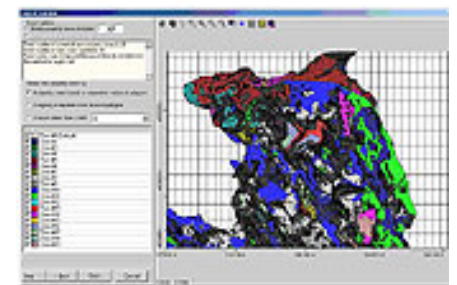
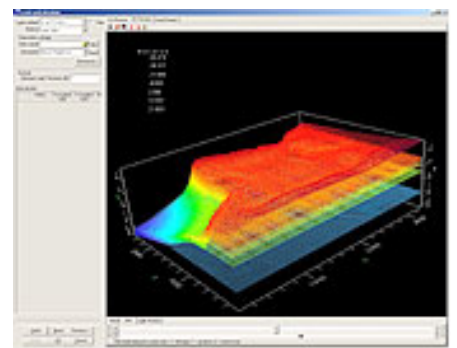
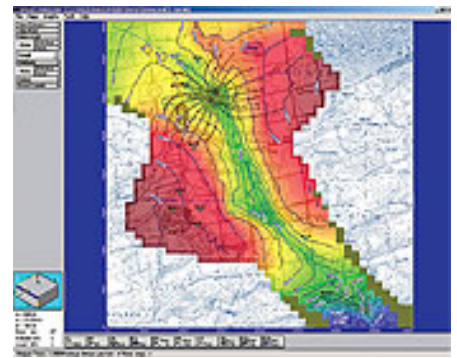
More Vibrant RGB Color Shading Options with Transparency - The drawing tools and algorithms used to render the color shaded contour maps include rich RGB color schemes with color map transparency.

Mapping of Property Zones from ESRI™ Polygon Shape Files - A quick and easy mapping feature now allows for automated mapping of property zones and recharge zones from ESRI Polygon Shape files (.SHP).

Enhanced Printing Options using a Flexible Page Layout - Visual MODFLOW 4.0 integrates a flexible page layout designer for adding image descriptions, project descriptions, and a company logo.

Expanded Color Management for Exporting and Capturing - Visual MODFLOW 4.0 provides a full suite of common graphical image formats to create (.GIF, .JPG, .TIF, .PNG, and .BMP) with options for increasing the image resolution and controlling the image quality-idea for high-quality reporting of modeling projects.

Export Virtually Any Model Property Value and Results Export virtually any model property values and simulation results to a variety of



ASCII and binary data formats including: ASCII XYZV (.TXT), ASCII Array (.TXT), Surfer Grid (ASCII) (.GRD), Surfer Grid (Binary) (.GRD)

* - sold as an add-on package exclusively by Waterloo Hydrogeologic, Inc.

Integrated Modeling Tools Give Groundwater Professionals the Technologic Edge!

Groundwater modelers are constantly balancing between software capabilities and computational speeds to meet industry demands. In many cases, more features and expanded simulation capabilities equates to steep learning curves and longer model run times. Visual MODFLOW includes direct access to several add-on packages, each designed to be fully integrated within the GUI to reduce the time you spending learning the features. Visual MODFLOW also includes direct access to solution methods that are proven to dramatically reduce model run time. Through Visual MODFLOW's streamlined interface design, and added modeling, calibration, and visualization add-on packages, you'll save time and money producing high-quality modeling reports!

WinPEST brings parameter estimation and predictive analysis to life. WinPEST has been seamlessly integrated into Visual MODFLOW to allow you to conveniently select the model parameters you want to optimize, and then easily launch the built-in WinPEST application directly from Visual MODFLOW. *Price: [Now US\\$470 \(Reg. \\$495\)](#)*

[Order Now!](#)

SAMG (Algebraic Multigrid Methods for Systems) is a highly efficient solver specifically designed for large projects to dramatically reduce run times of your complex models.

Price: [Now US\\$445 \(Reg. \\$495\)](#) [Order Now!](#)

MT3D99 is an ideal tool for simulating groundwater plume migration in either two- or three-dimensional groundwater flow systems. *Price: [Now US\\$595 \(Reg. \\$695\)](#)*

The **Visual MODFLOW 3D-Explorer** is a built-in 3D visualization add-on used for displaying and animating Visual MODFLOW models using state-of-the-art 3D graphics technology. *Price: [Now US\\$850 \(Reg. \\$895\)](#)*

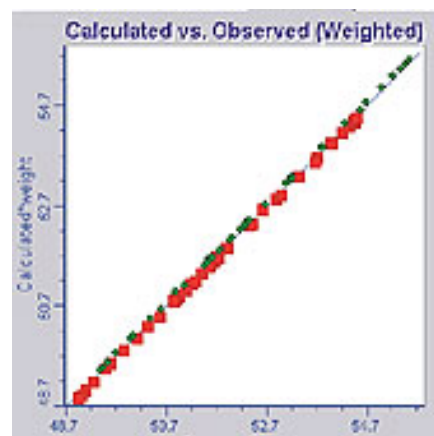
MODFLOW-SURFACT flow modules seamlessly integrate into Visual MODFLOW giving you the ability to perform unsaturated-saturated flow modeling with one package.

Price: [Now US\\$995 \(Reg. \\$1095\)](#)



To learn more about
Visual MODFLOW 4.0
[download a
free demo today!](#)

**SAVE ON
VISUAL MODFLOW
ADD-ON PACKAGES UNTIL
JUNE 30th, 2004!**



[WinPEST](#)



Visual MODFLOW Companion Products!

Utilize **Surfer*** to perform 2D contouring and surface plotting of your data to create outstanding contour maps and surface plots. Interpolate your model layers, and import directly into Visual MODFLOW! *Price: [Now US\\$575](#)*

WHI UnSat Suite* is an unsaturated zone modeling application used to develop site specific contaminant loading rates for use in Visual MODFLOW.

*Price: [Now Only \\$595 \(Save \\$100\)**](#)*

Visual HELP* is an unsaturated zone modeling application used to develop site specific groundwater recharge estimations for use in Visual MODFLOW.

*Price: [Now Only US\\$695 \(Save \\$100\)**](#)*

Contact a WHI Sales Representative today to find out more about the valuable add-ons to [Visual MODFLOW](#).

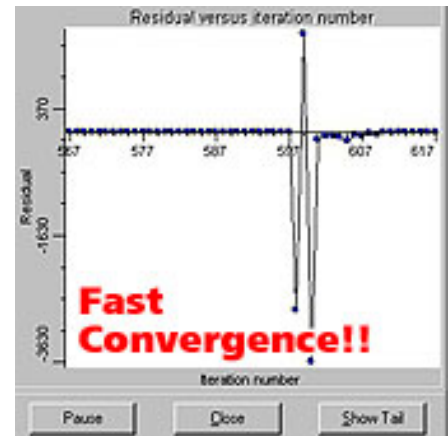
Special combo pricing is available. Call for details!

For more information about our software, please visit our website or contact us today:

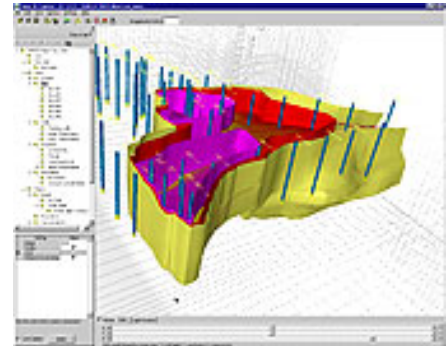
Web: Website: <http://www.waterloohydrogeologic.com>

Email: sales@waterloohydrogeologic.com

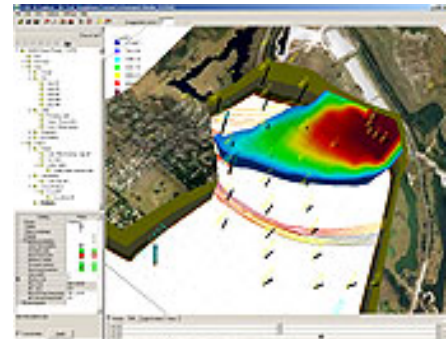
Phone: (519) 746-1798



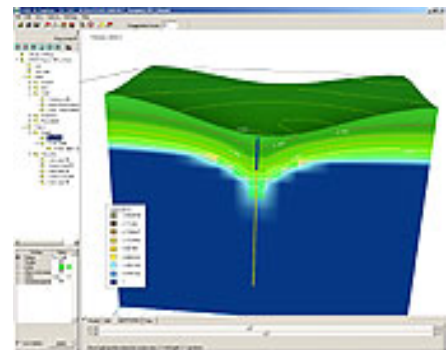
[SAMG](#)



[MT3D99](#)



[VMOD 3D-Explorer](#)



[MODFLOW SURFACT](#)

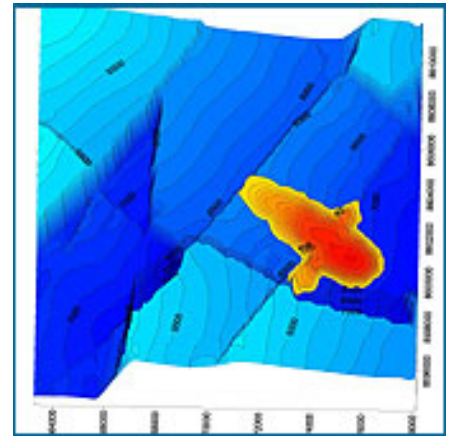
* Available as a separate package
** Offer valid until June 30th, 2004

Note on Beta Testing Program for Visual Modflow 4.0

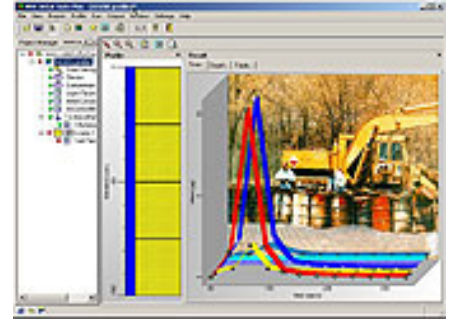
We are proud to announce that the Visual MODFLOW v.4.0 beta testing program was a big success, with over 110 participants. We very much appreciate the time that the beta testers took to evaluate the software and send us their findings. We are confident that with the implementation of many of your suggestions, the release of version 4.0 will be the best release ever! Those suggestions that have not been included in this release will be considered for future software updates.

As a token of WHI's appreciation for the major contributions of **Mr. Yves LeBlanc, Mr. Michael Gonshor, and Mr. Andrew DeMarchant**, and for their commitment and enthusiasm, we are pleased to announce that they will receive a free upgrade for Visual MODFLOW PRO 4.0!

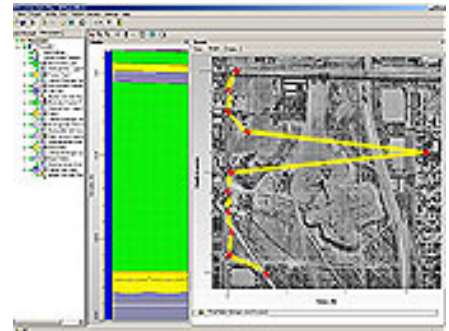
We are particularly thankful for the contribution of the following individuals listed to the right, for their outstanding efforts in testing our code, and for the many useful suggestions they made throughout the Beta Testing program.



[Surfer](#)



[WHI UnSat Suite](#)



[Visual HELP](#)

Andrew DeMerchant, GEMTEC Ltd.
Arve Misund, Interconsult ASA
Bosco Y. Lee, Gartner Lee Limited
Brian Barnett, Sinclair Knight Merz
Burri Jean-Marc, Spain
Christopher Munro, Gartner Lee Ltd.
Dawood Muhammad, CH2M HILL Ltd.
François A. Richard, Wesa
Gregory P Wittman, Kleinfelder, Inc.
Hongze Gao, Franz Environmental Inc
Hugh McCreadie, GeoSyntech
Leon Chen, Kerr-McGee Shared Services,
LLC
Michael Gonshor, Roux Associates, Inc.

Michael Jorgensen, URS Australia Pty Ltd
Oleg Podolny., KazHYDEC
Patrick Delaney, PDM, Brazil
Peter A. Mock, Peter Mock Groundwater Consulting, Inc.
Peter Bannister, Aspect Consulting
Peter J. Randazzo, Brown & Caldwell
Tjaard van Ellen, Aquaconseil sprl
Yves Leblanc, Richelieu (Qc)

For more information about our software, please visit our website or contact us today:

Website: http://www.waterloohydrogeologic.com/software/software_main.htm

Email: sales@waterloohydrogeologic.com

Phone: (519) 746-1798



Consulting News

Teaming is One of Our Keys to Successful Project Delivery

Each month in this section of the WHI E-News, our Consulting Division highlights examples of our groundwater projects. These examples describe a wide variety of hydrogeologic conditions as they are derived from projects across Canada, the United States, and South America, as well as other locations that include Africa, Asia, the Caribbean, and the Middle East. It is hoped that by sharing our experiences we are able to:

- Assist others with similar projects
- Demonstrate our range of capabilities
- Promote collaboration and teaming arrangements for future projects

In most cases, our staff are members of consultant teams that are assembled to complete multi-faceted projects, where hydrogeology is one of the technical components. We have been partners on projects such as watershed studies, source protection planning, water supply and water re-use planning, aquifer recharge feasibility, water quality assessments, web-enabled environmental data management systems, water well tagging development and implementation, risk assessment, and water budget analyses, among others.

Waterloo Hydrogeologic, Inc.'s wealth of consulting experience is derived from our staff of professionals, each with different backgrounds and experiences, working as team members to effectively resolve a variety of environmental challenges. Our staff includes:

- Professional Engineers
- Professional Geoscientists and Geologists
- Hydrogeologists



- Data Management Specialists
- GIS and Mapping Specialists
- Environmental Technicians

Our capabilities include the various stages of groundwater projects such as site characterization and monitoring, data management and GIS, and groundwater modeling. We provide consulting services in the following key areas:

- Groundwater Resources Management
- Environmental Impact and Risk Assessment
- Contaminated Site Solutions
- Advanced Groundwater Modeling Solutions
- Environmental Solutions for Mining
- Environmental Data Management
- Model Review and Litigation Support

We're convinced that our experience in developing technological solutions in these areas can be applied to help you effectively protect and manage groundwater resources.

With offices in Tampa, Florida, Sao Paulo, Brazil, and Waterloo, Ontario, our consulting staff are currently pursuing opportunities locally and internationally. We welcome the opportunity to discuss teaming partnerships with you to provide solutions to a wide variety of groundwater and environmental challenges. Please contact us as follows:

Call us in Tampa at (813) 622-9700, or e-mail us at consulting-usa@waterloohydrogeologic.com

Call us in Sao Paulo at +11-3030-9344, or e-mail us at whs@waterloo.com.br

Call us in Waterloo at (519) 746-1798, or email us at consulting@waterloohydrogeologic.com

Modeling and Watershed Management

Together with Credit Valley Conservation (CVC), WHI recently presented our approach to regional groundwater modeling for watershed management and water budget analysis at the Canadian Water Resources Association Seminar "Water Budget Analysis on a Watershed Basis". The audience included representatives from Conservation Authorities, Municipalities, and consultants. CVC is a leader in watershed management in Ontario, and the model developed by WHI for CVC was showcased as an invaluable tool for watershed management (see [January 2004 E-news](#)). The presentation outlined the details of the modeling approach, from defining the model objectives and data needs, to conceptual model development, to cross-section



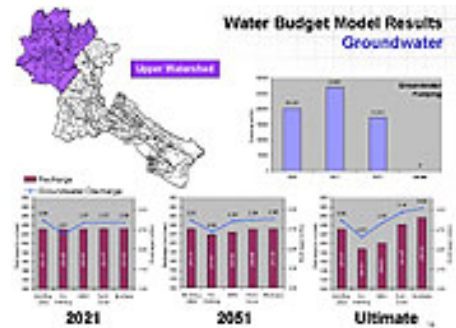
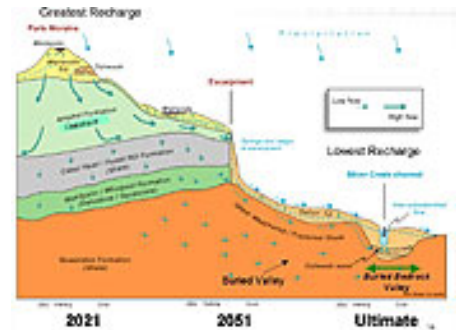
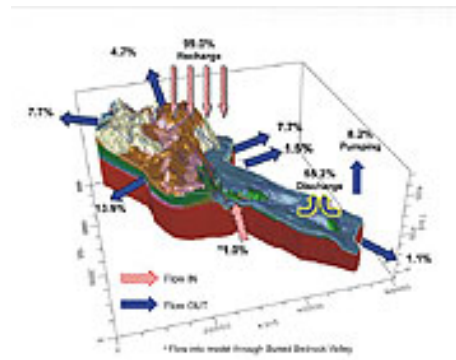
interpretation, to consideration of scale of application and construction of the numerical model. The FEFLOW (WASY, 2004) finite element model developed for CVC is a tool being applied and updated to assess impacts from a variety of development scenarios at both the watershed and subwatershed scales, including assessment of impacts on surface water. The tool is currently being applied to a number of projects including the Updated Credit River Water Management Strategy, which has shown that expected development impacts may be mitigated with the adoption of appropriate management options. The ability to assess impacts in this manner extends the model beyond simple water budget analysis to watershed management.

For additional information regarding WHI's experiences during this project, please contact Daron Abbey.

Daron Abbey

Email: dabbey@waterloohydrogeologic.com

Phone: (519) 746-1798 Ext 224



If you would like more information about WHI's Consulting activities and capabilities, visit our website or contact us today:

Website: www.waterloohydrogeologic.com/consulting/consulting_services.htm

Email: consulting@waterloohydrogeologic.com

Phone: (519) 746-1798

▲ TOP

Training News

WHI Now Offering a New Line-Up of Environmental & Groundwater Modeling Courses!

The 2004 Waterloo Hydrogeologic Open Enrollment schedule has been set. In response to comments from groundwater professionals who have taken our Groundwater Modeling Courses in the past, and those who would like to attend courses in the future, WHI has combined the strengths of our previous Groundwater Modeling, Advanced Groundwater Modeling, and Model Calibration courses into one [Applied Groundwater Flow & Contaminant Transport Modeling](#) course. This course will include updated lecture material, as well as new hands-on laboratories to support the new course material. WHI has also created a new short course entitled [GIS Data Management for Groundwater Modelers](#), which teaches the theory and hands-on application of GIS data integration and interpolation to support groundwater modeling efforts, as well as 3-dimensional visualization of modeling results in both the Visual MODFLOW and GIS environments.

Click on the titles below and see which courses are appropriate for you!

- » [Applied Groundwater Flow & Contaminant Transport Modeling](#) - **NEW**
- » [Groundwater Contamination & Remediation](#) - **UPDATED**
- » [Finite Element Groundwater Modeling](#) - **UPDATED**
- » [Aquifer Test Analysis](#) - **NEW**
- » [Unsaturated Zone Modeling and Evaluation of Landfill Impacts](#) - **UPDATED**
- » [The Human Health Risk Assessment Course](#) - **NEW**
- » [Water Quality Data Management & Modeling](#) - **UPDATED**
- » [Regulatory Review of Hydrogeology Studies](#) - **UPDATED**
- » [GIS Data Management for Groundwater Modelers](#) - **NEW**

Who Can Benefit?

- » Experienced hydrogeologists with no prior groundwater modeling experience;
- » Regulators who review modeling reports;
- » Managers who want to understand what the modelers are doing;
- » Experienced modelers who want to enhance their skills;
- » Students who want to acquire new skills;
- » Lawyers who want to understand some of the technical issues; and
- » Industry professionals who want to understand more about what their consultants are telling them.

For further details on any of these courses, please visit our [website](#), or contact Miln Harvey, WHI Training Manager, at (519) 746-1798 x233.

Can't make one of our Open Enrollment Courses? Call us about our On-Site Custom courses designed to suit your specific needs!

Course Title

Dates/Locations

APPLIED GROUNDWATER FLOW & CONTAMINANT TRANSPORT MODELING



Theory and Hands-on Applications using MODFLOW-2000, MODPATH, MT3D & WinPEST

Simple to complex applications of groundwater flow and contaminant transport models are covered in this 4-day hands-on course. Groundwater resource topics include model development and calibration to groundwater heads and flows, new well development, capture zone delineation, well interference and stream impact investigations. Contaminant transport topics include model development and calibration to contaminant concentration, source area design, concentration boundary choice, solver comparison, and 3D visualization of flow and transport results. This course is ideally suited for hydrogeologists and modelers with some field investigation and modeling experience who wish to advance their modeling knowledge, and whose responsibilities include model development, review, planning and project management.

Course Objectives and Benefits

- » Apply Visual MODFLOW Pro to 3D groundwater flow and contaminant transport projects
- » Use MODFLOW-2000 to develop several groundwater flow models
- » Calibrate your groundwater models to observed field data
- » Use MODPATH particle tracking features to determine preferential flow paths and delineate capture zones
- » Use ZoneBudget to assess subregional water budgets within your groundwater model
- » Simulate 3D contaminant transport using RT3D, MT3DMS & MT3D99
- » Use WinPEST to improve model calibration and understand model uncertainty

[Budapest, Hungary](#)
[May 10 - 13, 2004](#)

[Waterloo](#)
[June 1 - 4, 2004](#)

[Rome, Italy](#)
[June 22 - 25, 2004](#)

[Lyon, France](#)
[June 29 - July 2, 2004](#)

[Buenos Aires, Argentina](#)
[July 5 - 8, 2004](#)

[Cambridge, UK](#)
[July 27 - 30, 2004](#)

[Waterloo, Canada](#)
[Sept 14 - 17, 2004](#)

[Krakow, Poland](#)
[October 11 - 14, 2004](#)

[Sapporo, Japan](#)
[October 19 - 22, 2004](#)

[Braunfels, Germany](#)
[October 25 - 29, 2004](#)

[**Register Now**](#)

CONTAMINATED SITE RISK ASSESSMENT AND GROUNDWATER MODELING



Transport Processes, Natural Attenuation and Risk Assessment

This course provides a more complete understanding of groundwater contamination and remediation, and the use of fate and transport models and risk assessment software for analysis. Topics that will be covered include contaminant source area characterization, the risk assessment process, the fundamentals of natural attenuation, and risk-based corrective action. This course is suited for groundwater modelers and risk assessors who wish to develop a better understanding of groundwater contamination and remediation, the risk assessment process, and the use of groundwater models to assess risk-based site-specific standards and contaminant remediation.

Course Objectives and Benefits

- » Define the Risk Assessment process and Risk-Based Corrective Action
- » Enhance your understanding of contaminant transport and natural attenuation processes
- » Detail how to quantify the potential risks of exposure to chemical contaminants
- » Link fate and transport models to risk-based decision making models
- » Quantitatively assess human health and ecological risk from environmental contaminants
- » Define site-specific target levels (SSTLs) for site clean-up goals

[Madrid, Spain](#)

[June 8 - 11, 2004](#)

[Johannesburg, South
Africa](#)

[June 22 - 25, 2004](#)

[Waterloo, Canada](#)
[August 10 - 13, 2004](#)

[Ostrava, Czech Republic](#)
[Sept 7 - 10, 2004](#)

[Gent, Belgium](#)

[Oct 26 - 29](#)

[Register Now](#)

WATER QUALITY DATA MANAGEMENT & MODELING



Applications using AquaChem and USGS PHREEQC

The large quantity and range of environmental groundwater data types presents a challenge to professionals who wish to develop a comprehensive interpretation of a suite of data. This course provides hands-on experience in temporal and spatial data interpretation, including the use of convenient computer software for organizing and plotting the data.

- » Planning a data collection program
- » Interpreting temporal and spatial data densities
- » Quality control issues
- » Applied geochemical modeling
- » How to use AquaChem

[Waterloo, Canada](#)
[May 12 - 14, 2004](#)

[Register Now](#)

FINITE ELEMENT GROUNDWATER MODELING



Advanced Applications for Saturated/Unsaturated Flow & Transport, Density-Dependent Flow, and Heat Transport

Advanced applications of groundwater flow and contaminant transport models using the Finite Element method are covered in this 4-day hands-on course. This course provides a more complete understanding of the use and applicability of finite elements in groundwater modeling, and includes such topics as groundwater flow and transport modeling, principles of unsaturated flow, fracture flow modeling, thermal transport, and density-dependent flow modeling. This course is ideally suited for groundwater modelers who wish to advance their modeling knowledge, and apply finite elements, using FEFLOW, to more complex modeling designs.

Course Objectives and Benefits

- » Understand when to use finite-element vs. finite-difference modeling
- » Apply FEFLOW to 3D groundwater flow and contaminant transport problems
- » Simulate unsaturated zone flow using FEFLOW
- » Simulate density-driven groundwater flow (e.g. saltwater intrusion) using FEFLOW
- » Simulate fracture flow modeling using FEFLOW, and compare to a research case study
- » Introduce the Interface Manager and the concept of model calibration to observed field data

[Waterloo, Canada](#)
[Nov. 2 - 5, 2004](#)

[San Francisco, CA](#)
[June 15 - 18, 2004](#)

[Register Now](#)

THE HUMAN HEALTH RISK ASSESSMENT COURSE



Practical Approaches to Estimating Risk & Developing Site-Specific Target Levels

An introduction to the use of RISC Workbench for completing human health risk assessments is covered in this 2-day course of lectures and hands-on exercises. Topics that will be covered include hazard identification, exposure assessment, dose-response assessment and risk characterization. Lectures and exercises will be presented in partnership with Lynn Spence, the developer of RISC Workbench. This course is suited for risk assessors who wish to develop a better understanding of the risk assessment process and the use of groundwater models and RISC Workbench software for completing a human-health risk assessment.

Course Benefits

- » Learn the fundamentals of accepted risk assessment protocols
- » Acquire lots of hands-on experience using the RISC Workbench software
- » Understand the practical aspects of conducting a risk assessment
- » Learn from an experienced risk assessment professional with worldwide experience

[San Francisco, CA](#)
[June 21 - 22, 2004](#)

[Cambridge, UK](#)
[August 2 - 3, 2004](#)

[Register Now](#)

AQUIFER TEST ANALYSIS



Principles of Pumping Test Design and Techniques for Data Analysis

A wide variety of techniques can be applied to analyzing aquifer tests. This course covers the theory behind the techniques and provides an opportunity to obtain hands-on experience in analyzing aquifer test data collected from a variety of conditions.

- » Planning a pumping test
- » Principles of aquifer test analysis
- » Porous and fractured media
- » Isotropic/anisotropic conditions
- » Confined, leaky, and unconfined aquifers

[Waterloo, Canada](#)
[August 17 - 18, 2004](#)

Register Now

REGULATORY REVIEW OF HYDROGEOLOGY STUDIES



Approaches and Insights for Reviewing Modeling Reports

The overall objective of this course is to give regulators a greater understanding of how models work, and what to look for when reviewing a modeling report. Specifically, the objectives are as follows:

- » To understand the uses and applications of numerical models;
- » To understand the uses and applications of the analytical WHPA model;
- » To have a practical basis for reviewing models;
- » To identify the points of focus for reviewing a modeling study;
- » To recognize when review by a specialist is required.

The content of this course will be applicable to the following areas:

- » Alternatives for landfill or septic system design;
- » Prediction of contaminant movement and impact from landfills, septic systems and contaminated sites;
- » Selection of remediation alternatives;
- » Delineation of well capture zones and groundwater protection areas;
- » Assessment of impacts from large groundwater extractions, and pit and quarry development in the context of the Permit To Take Water Program (PTTW) and groundwater interference investigations.

These applications could include review of modeling studies submitted by consultants, evaluation of workplans submitted by owners/proponents and specification of modeling requirements for tendering hydrogeological studies.

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Tips & Tricks

Using Cutting Edge Optimization Technologies With Visual MODFLOW Version 4.0

Overview of Optimization Technologies

There are two common approaches used when solving an optimization problem:

Approach 1: Best engineering judgment, plus repetitive simulation modeling (trial and error)

Approach 2: Best engineering judgment, plus simulation/optimization modeling

Optimization models have recently gained importance and popularity after a comprehensive study funded by the US-Department of Defense (DoD). The study concluded that simulation/optimization modeling is considerably more cost effective (cost savings around 20%) than the traditional approach (ESTCP Report CU-0010).

Some applications of Optimization technology include:

Application	Objective	Typical Constraints
Well field optimization	Obtain optimal well locations and pumping rates in order to maximize water extraction	Maximum drawdown usually restricted (in sensitive areas or at the well field) Maximum reduction in baseflow to streams Maximum concentration of specific parameters Costs

Remediation design (pump and treat, funnel and gate systems etc.)	Obtain optimal well locations and pumping/injection rates for each well Maximum Mass removal rates Minimize contaminant concentration in treatment zones Plume confinement	Specified maximum concentrations at compliance points (trigger monitoring wells, property limit, etc.) Gradient toward confinement area (to avoid off-site migration) Maximum drawdown may be restricted (in sensitive areas or at the well field) Total pumping rate usually limited (Wastewater treatment restrictions) Extraction rate equal to Injection rate in some cases. Costs
Dewatering	Obtain minimum number of extraction wells to dewater a site to a specific maximum head elevation	Maximum head elevation at the excavation site Total pumping rate often limited to existing pumping capacity or discharge limits Maximum drawdown at sensitive areas Costs

There are three fundamental elements in an optimization problem. They are:

- Decision variables,
- Objective function, and
- Constraints.

A **decision variable** is one that water managers assumedly can directly control, such as **groundwater extraction or injection rates, well locations** and the **on/off status** of a well. A **Constraint** is a condition that must be satisfied by the optimal water management strategy computed by the simulation/optimization model. Constraints can refer to

bounds on decision variables and state variables, such as ensuring a minimum head elevation at a wetland, or a maximum elevation at an open mine pit; and/or contaminant concentrations, such as a maximum value of PCE at the property limit.

The goal of simulation/optimization modeling is to adjust operational parameters (system design in groundwater problems usually include parameters such as well locations, well screen locations, and pumping rates) in order to minimize (or maximize) a defined cost function called the **objective function**. The **objective function** is defined by the user and may include actual costs such as well drilling, pump and treatment, or may include hypothetical penalty costs of incomplete cleanup.

Using Optimization Technologies with Visual MODFLOW

Visual MODFLOW has a very intuitive user interface, and follows the best practices and logic steps to form an optimization problem. The steps to generating an optimization problem include:

- Picking decision variables (operational parameters) to be optimized. You can select some, or all, wells defined in your flow model to be decision variables. You can also define specific groups for the decision variables. (See *Figure 1*).
- Establishing constraints, i.e. defining limits of acceptable values for decision variables and system responses (also called state variables such as head, concentration, etc).
- Creating an objective function to be minimized (or maximized). For example, you may want to maximize mass removal in a remediation system, and
- Choosing an appropriate optimization algorithm and its control parameters

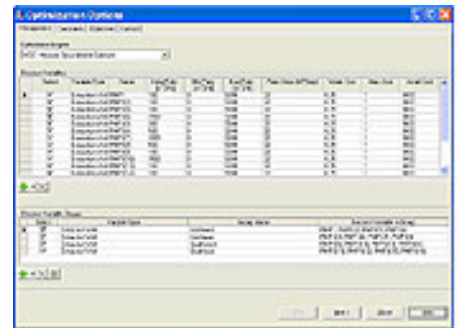


Figure 1

Main features of Visual MODFLOW related to simulation/optimization modeling

- Automatically extracts available decision variables and control locations from your flow/transport model.
- Performs rigorous data validation between simulation model and optimization model. For example, if a well (used as a decision variable) is removed from the simulation model, Visual MODFLOW will automatically display a message to show which decision variable is missing. Either you can add the well back into your simulation model, or simply delete it from your optimization model.
- Checks for optimization data integrity.
- Creates different scenarios very quickly.
- Allows the modeler to focus on the problem of concern, instead of worrying about file input formats and data tables.
- Prepares all required input data files and automatically runs the optimization engine.
- Allows users to easily make sense of the optimization results by

displaying the progress of objective minimization (or maximization), *See figure 2a*. It also displays well optimization results using well names instead of row/column/layer location data (*See figure 2b*).

Optimizing the optimization process

Optimization modeling usually requires running hundreds of simulations. This involves a considerable amount of time for large, complex models. Therefore, starting from a simple scenario is always recommended. The following tips can assist you in optimizing your optimization model:

- Start from a simplified approach and gradually add complexity to your model, using your gained knowledge from the optimization process.
- Break your problem down into sub-problems. For example, fix pumping rates at capacity and optimize well locations first; then fix well locations and optimize pumping rates.
- Try to reduce model file size. For instance, reduce grid discretization wherever possible in the early stages of the optimization process. Add more cells where you require a better solution after a preliminary design optimization is obtained.
- If possible, with transient runs, use fewer time steps, or break the transient problem into different phases.
- Choose the fastest solver for your specific problem. A few minutes per run may add up after numerous simulations.

Unlike model parameter estimation, multiple optimal solutions are possible and some are equally acceptable. Even if the optimization does not achieve an optimal solution, extremely valuable and insightful knowledge can be gained through the process. For example, a proposed mine dewatering using pumping wells alone may not be feasible for that particular mine site, or perhaps the pump & treat solution for another site may be overkill.

Figure 3 shows the Result of an extraction/injection well system optimization in a dewater example. Only four extraction wells (out of 16 initially considered) were necessary to meet project goals, with considerable cost savings!

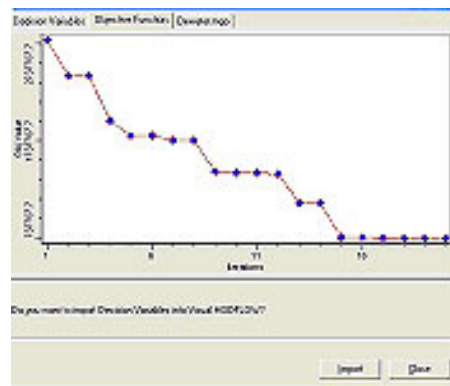


Figure 2a

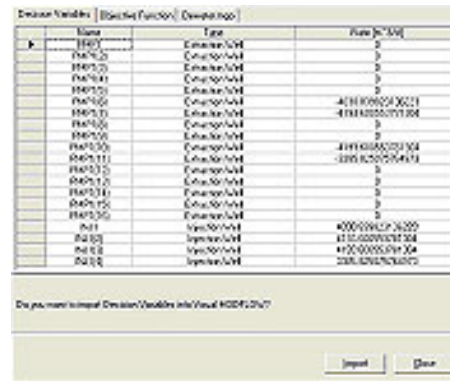


Figure 2b

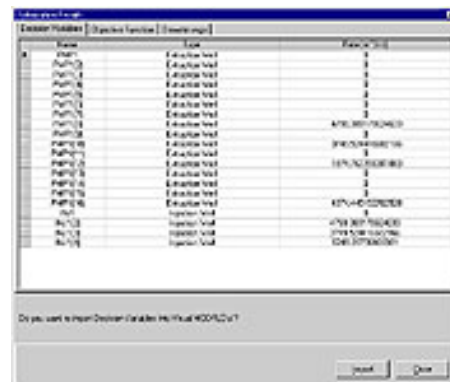


Figure 3

Technical Highlights

Highlights from the Transport Optimization Short Course in Golden, Colorado

Dr. Benny Bian, software project leader from Waterloo Hydrogeologic, Inc., participated in the "Transport Optimization Short Course" on March 17-19 2004 in Golden, Colorado. This course was part of the DoD ESTCP (Environmental Security Technology Certification Program) demonstration project, and was sponsored by ESTCP and EPA-TIO.

On March 17 and March 18, the newly-released Visual MODFLOW Version 4.0 was demonstrated during several seminars. The integration into Visual MODFLOW of the MGO and SOMOS optimization engines received great interest from course participants. The presentation of Visual MODFLOW Version 4.0 features and capabilities received positive comments particularly from Dr. Chunmiao Zheng (one of the course instructors, and creator of MGO), Dr. Richard Peralta (one of the course instructors, and creator of SOMOS), Mr. Dave Becker (USACE), Dr. Kan Tu (HydroGeoLogic, Inc.), and Dr. Gilbert Barth (S. S. Papadopoulos & Associates, Inc). Course participants expressed great interest the opportunity for further hands-on training in optimization technologies.

Dr. Bian interviewed Dr. Barbara Minsker during the seminar. Dr. Minsker was an instructor at the short course. She was recently awarded the ASCE Water L. Huber Civil Engineering Research Prize for her work on "Optimization of groundwater remediation and monitoring design and effective and efficient use of genetic algorithms". The following are excerpts of their interview:

Dr. Bian: "How do you comment on the current status of optimization technologies?"

Dr. Minsker: "It is a very exciting time for people working in this field. There are enormous interests in the technology. The upcoming optimization conference sponsored by the EPA received more than 200 abstracts. There is still active research underway on challenges like handling multi-objective optimization problems and optimizing under uncertainty, but substantial progress has been made and people have started using optimization to solve real, complicated problems."

Dr. Bian: "What is your view about applicability of optimization technology?"

Dr. Minsker: "Simple problems can usually be handled with traditional trial and error approaches, but optimization technology is a great tool for problems with large numbers of potential decision options. I agree with the view that the best engineering judgment is always a prerequisite for any approach, either traditional trial and error or simulation/optimization methods. Solving any problem must always be done by people plus computers, not just computers."

Waterloo Hydrogeologic, Inc. has implemented both the MGO and SOMOS optimization engines in Visual MODFLOW Version 4.0. The initial release of Version 4.0 will include the MGO optimization engine, and the SOMOS engine will be released in the near future. For more information about the optimization capabilities of Visual MODFLOW Version 4.0, or to purchase the software, please contact [WHI's Sales department](#) or [see our](#)

[website!](#)

For more information about this tip, contact us at:

Email: techsupport@waterloohydrogeologic.com

For more information about [Visual MODFLOW Pro 4.0](#), visit our website or contact us today:

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