FAQ

1. What is the analytic element method?

The analytic element method for regional groundwater modeling was developed at the end of the seventies by Otto Strack at the University of Minnesota (Strack and Haitjema, 1981a). There are two books about the analytic element method, Groundwater Mechanics by O. D. L. Strack, Prentice Hall, 1989, contains detailed mathematical descriptions of the analytic elements and their numerical implementation. Analytic Element Modeling of Groundwater Flow by H. M. Haitjema, Academic Press, 1995, provides the basic theoretical framework for the analytic element method and focuses on its use. This new method avoids the discretization of a groundwater flow domain by grids or element networks. Instead, only the surface water features in the domain are discretized, broken up in sections, and entered into the model as input data. Each of these stream sections or lake sections is represented by closed form analytic solutions: the analytic elements. The comprehensive solution to a complex, regional groundwater flow problem is obtained by superposition of all, a few hundred, analytic elements in the model. Traditionally, superposition of analytic functions was considered to be limited to homogeneous aquifers of constant transmissivity. However, by formulating the groundwater flow problem in terms of appropriately chosen discharge potentials, rather than piezometric heads, the analytic element method becomes applicable to both confined and unconfined flow conditions, as well as to heterogeneous aquifers (Strack and Haitjema, 1981b). The analytic elements are chosen to best represent certain hydrologic features. For instance, stream sections and lake boundaries are represented by line sinks, small lakes or wetlands may be represented by areal sink distributions. Areal recharge is modeled by areal source distributions (areal sinks with a negative strength). Streams and lakes that are not fully connected to the aquifer are modeled by line sinks or area sinks with a bottom resistance. Discontinuities in aquifer thickness or hydraulic conductivity are modeled by use of line doublets (double layers). Specialized analytic elements may be used for special features, such as drains, cracks, slurry walls, etc. Locally three-dimensional solutions may be added, such as a partially penetrating well (Haitjema, 1985). Strack (2003) provides a recent review.

References

1. Strack, O.D.L. & Haitjema, H.M. (1981a). Modeling double aquifer flow using a comprehensive potential and distributed singularities 1. Solution for homogeneous permeabilities. Water Resour.Res., 17(5):1535-1549.
2. Strack, O.D.L. & Haitjema, H.M. (1981b). Modeling double aquifer flow using a comprehensive and potential and distributed singularities 2. Solution for inhomogeneous permabilities. Water Resour.Res., 17(5):1551-1560.
3. Haitjema, H.M. (1985). Modeling three-dimensional flow in confined aquifers by superposition of both two- and three-dimensional analytic functions. Water Resour.Res., 21(10):1557-1556.
4. Strack, O.D.L. (1989). Groundwater Mechanics, Prentice Hall, www.strackconsulting.com.
5. Haitjema, H.M. (1995). Analytic Element Modeling of Groundwater Flow. Academic Press, Inc., www.haitjema.com
6. Strack, O.D.L. (2003). Theory and applications of the analytic element method, Reviews of Geophysics, 41,2/1005 2003, doi:10.1029/2002RG000111

SLIDE PRESENTATION

Bakker, Mark, and Stephen Kraemer, 2001. Groundwater modeling with analytic elements: cultivating understanding of groundwater systems, EPA/NERL/ERD Seminar, Athens, GA, March 8.

Part I and II	(PDF, 20 pp., 306 KB, about PDF)
Part IIIa	(PDF, 13 pp., 244 KB, about PDF)
Part IIIb	(PDF, 19 pp., 612 KB, about PDF)
Part IV	(PDF, 13 pp., 303 KB, about PDF)

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2. Where can I get analytic element models?

PRESS RELEASES
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MODELING SYSTEMS

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SLWL
Web: strackconsulting.com/home (comes with book Groundwater Mechanics)
License: Free
Version: 1.1 (1989)

"SLWL is a Fortran code for flow in single layer homogenous aquifers including functions for wells, line sinks, ponds, uniform flow, and rainfall recharge functions."
Otto Strack
Strack Consulting, Inc.
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CZAEM
Web: www.epa.gov/ada/csmos/models/czaem.html
License: Free
Version: 1.1 (1996)

"The Capture Zone Analytic Element Model (CZAEM-DOS by Otto Strack and others) is a single layer model for simulating steady flow in homogeneous aquifers using the analytic element model. It serves as a tool in the wellhead protection decision-making process by delineating capture zones and isochrones of residence times. The command line package includes analytic elements for wells, rivers, and recharge. The sophisticated capture zone maps are generated by determining all stagnation points and dividing streamlines in the regional flow domain."
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ModAEM
Web: modaem.sourceforge.net
License: Open source GPL
Version: 1.4-alpha 1 (2001)

"A high performance, open source, analytic element code, written in object-based Fortran, designed for interfacing with other models or GUIs. ModAEM is highly modular in design, parallelizable, and a production code. ModAEM was the solution engine for the EPA modeling system WhAEM2000 version 1, and is currently used in GMS.

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GFLOW-EPA
Web download: ftp://ftp.epa.gov/sandyrun/WhAEM_Development/Solver/
License: Open source, artistic license (contact Kraemer for details).
Version: (2004)

"An open source version of the GFLOW solution engine by Henk Haitjema that is part of the EPA modeling system WhAEM2000 version 2."

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3DFlow
Web download: groundwater.ce.ksu.edu/
License: Free
Version: 2x3 (2001)

"3DFlow is a public domain, interactive computer tool that models and visualizes 3D groundwater flow. This tool simulates steady flow to horizontal wells, partially penetrating wells, and fully penetrating wells in a regional field of uniform flow. Aquifer features may be located in a horizontal aquifer bounded by two planes, in a semi-infinite aquifer bounded by one horizontal plane, or in an aquifer that is infinite in extent. 3DFlow provides an interactive learning environment with pull-down menus and projection of a 3D view region on the screen."

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Split
Web download: www.groundwater.buffalo.edu/software/software.html
License: Free
Version: 3.0 (2005)

"Split is a program for analytic modeling of single-layer groundwater flow in heterogeneous aquifers. Split includes particle tracking, capture-zone delineation, and parameter estimation. Split supports modeling of inhomogeneities bounded by polygons, spatially variable recharge, rivers and lakes with bed resistance, discharge- and head- specified boundaries, and many other features. The only input is hydrogeologic features. The user is not required to make decisions that affect the numerics of the underlying computational engine." SPLIT is the solver implemented in Visual Bluebird and ArcAEM

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PhreFlow
Web download: www.groundwater.buffalo.edu/software/software.html
License: Free
Version: 1.1 (2001)

“PhreFlow models 3D transient flow and advective transport in a domain bounded by an impermeable base, a phreatic surface with recharge, and head specified lateral boundaries. The domain may contain an arbitrary number of wells of any orientation and inhomogeneities shaped as rotational ellipsoids of arbitrary conductivity. The well discharges and recharge can vary with time. PhreFlow uses a combination of the analytic element method to account for spatial distribution of heads and discharges and a finite difference method to account for transient conditions. PhreFlow outputs include heads, particle pathlines and capture zones. The programs Split and PhreFlow have also been used to investigate macroscopic dispersion. Research versions of these programs allow for implementation of as many as 100,000 circular inhomogeneities in 2D (Split) and 10,000 inhomogeneities shaped as rotational ellipsoids in 3D (PhreFlow) with analytic accuracy. The programs, including examples, manuals, references and movies depicting the dispersion process, may be downloaded from the web site above.”

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Tim
Web: http://www.engr.uga.edu/~mbakker/tim.html
License: Open Source GPL
Version: TimML 2.1 (2005)

“The main objective of the Tim project is to develop free, open source, object-oriented software for modeling of groundwater flow using analytic elements. Two programs have been developed: a single version TimSL, and a multilayer version TimML. The programs have a full object-oriented design that was developed with the input from a large group of analytic element developers. The Tim codes are open-source computer programs, which means that the source code is freely available and the user can make any modifications they like. Furthermore, when users develop features that may be useful for other users, they are supposed to give their developments back to the Tim project so that they can be included in the official release. The object oriented design of the Tim codes are basic, but flexible, so it is easy to learn how the program is structured and to make changes or additions. The Tim codes are written in Python. Python is an interpreted, interactive, object-oriented programming language. Python is powerful yet the syntax is surprisingly clear (it is easy to learn). Python runs on virtually any operating system, including Unix, Linux, Mac, and Windows. Python is open source, so you can download it for free from the web (www.python.org).”

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MODELING SYSTEMS

WhAEM2000
Web download: http://www.epa.gov/athens/software/whaem/index.html
License: Open source artistic license
Version: 3.2 (June 2005)

The U.S. EPA's Wellhead Analytic Element Model, WhAEM2000 for Windows (98/NT/XP), is a ground water geohydrology computer program. WhAEM2000 is a public domain, ground-water flow modeling system designed to facilitate capture zone delineation and protection area mapping in support of the State's Wellhead Protection Programs (WHPP) and Source Water Assessment Planning (SWAP) for public water supply wells in the United States. WhAEM2000 provides an interactive computer environment for design of protection areas based on radius methods, well in uniform flow solutions, and geohydrologic modeling methods. Protection areas are designed and overlaid upon US Geological Survey Digital Line Graph (DLG) or other electronic base maps. Base maps for a project can be selected from a graphical index map for the State. Geohydrologic modeling for steady pumping wells, including the influence of hydrological boundaries, such as rivers, recharge, and no-flow contacts, is accomplished using the analytic element method.

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GFLOW
Web download: www.haitjema.com
License: Proprietary
Version: 2.1.0 (June 2005)

“GFLOW is a highly efficient stepwise groundwater flow modeling system developed by Haitjema Software, a subdivision of Haitjema Consulting, Inc. GFLOW is a Windows 98/NT/XP program based on the analytic element method. It models steady state flow in a single heterogeneous aquifer using the Dupuit-Forchheimer assumption. While GFLOW supports some local transient and three-dimensional flow modeling, it is particularly suitable for modeling regional horizontal flow. To facilitate detailed local flow modeling, GFLOW supports a MODFLOWextract option to automatically generate MODFLOW files in a user defined area with aquifer properties and boundary conditions provided by the GFLOW analytic element model. GFLOW also supports conjunctive surface water and groundwater modeling using stream networks with calculated baseflow.”

“For more information on using the analytic element method for groundwater flow modeling see the textbook "Analytic Element Modeling of Groundwater Flow" by Henk Haitjema, Academic Press, 1995. See also Amazon.com.”

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VisualBlueBird
Web download: www.groundwater.buffalo.edu/software/VBB/VBBMain.htm
License: Free, requires Surfer ®.
Version: 2.0 (2005)

"A Visual Basic Windows GUI that supports regional and local scale modeling, confined and unconfined single-layer aquifers, capture zone delineation, particle tracking, inverse modeling of recharge and conductivity, manual and automatic calibration tools, advanced output options (Arcview 3.01®, Surfer®), multiple basemaps, pre and post processing in Surfer®. The user interface has been designed to operate with SPLIT, BLUEBIRD/CARDINAL (reactive transport solver), and OSTRICH (optimization and parameter estimation)."

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ArcAEM
Web download: http://www.groundwater.buffalo.edu/software/ArcAEM/ArcAEMMain.html
License: Open Source
Version: 2.13 beta

"ArcAEM is an extension to ESRI ArcGIS™ 8.x/9.x that enables the development, analysis, and calibration of analytic element models from within ArcMap™. ArcAEM provides an easy-to-use interface for configuring the input files for the groundwater flow model SPLIT, which solves the two-dimensional steady-state saturated flow equation using the analytic element method (AEM). ArcAEM also provides a variety of tools for automated configuration, checking, and simplification of applications containing thousands of elements."

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WINFLOW
Web download: www.groundwatermodels.com/software/software.asp
License: Proprietary

"WinFlow is a powerful yet easy-to-use groundwater flow model. WinFlow is similar to Geraghty & Miller's popular QuickFlow model which was developed by one of the authors of QuickFlow. The most notable improvement over QuickFlow is compatibility with Microsoft Windows V3.1/95/NT. WinFlow is a true Windows program incorporating a multiple document interface (MDI). WinFlow is an interactive analytical model that simulates two-dimensional steadystate and transient groundwater flow. The steady-state module in WinFlow simulates groundwater flow in a horizontal plane using analytical functions developed by Strack (1989). The transient module uses equations developed by Theis (1935) and by Hantush and Jacob (1955) for confined and leaky aquifers, respectively. Each module uses the principle of superposition to evaluate the effects from multiple analytical functions (wells, etc.) in a uniform regional flow field."

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TWODAN
Web download: www.fittsgeosolutions.com
License: Proprietary
Version: 5.0 (1998)

"TWODAN stands for TWO-Dimensional ANalytic groundwater flow model. Version 5.0 combines advanced analytic elements with an excellent user interface. It is a 32-bit Windows application with a familiar and simple user interface. TWODAN's capabilities, interface quality, and price make it a great value for 2-D flow modeling. It is a good tool for many remediation design, capture zone analysis, and regional modeling problems."

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SLAEM, MLAEM/2, MLAEM
Web download: strackconsulting.com/home
License: Proprietary
Version: 5.02 (1997)

"The AEM family of computer programs, presently SLAEM, MLAEM/2, and MLAEM, are based on the Analytic Element Method, developed by Dr. O.D.L Strack. For a description of the Analytic Element Method, see Groundwater Mechanics by O.D.L Strack (Prentice-Hall, 1989). The computer programs are intended for modeling regional groundwater flow in systems of confined, unconfined, and leaky aquifers. SLAEM (Single Layer Analytic Element Model) is the single-layer version of the program, MLAEM/2 (Mulit Layer Analytic Element Model) can access 2 layers, while the number of layers supported by MLAEM is limited only by hardware. All programs run under UNIX (on Sun computers) and under Microsoft Windows® 95 and NT®. The programs are native windows applications and are accessed via a modern and flexible Graphical User Interface (GUI), as well as via a command-line interface. The latter capability makes it easy to drive the program from other programs like ArcView, ArcInfo, and PEST. The programs create files from data entered graphically via the GUI; these files can be read in later. The programs read DXFfiles and produce BNA files that may be read by other programs, such as SURFER."

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GMS
Web download: http://chl.erdc.usace.army.mil/CHL.aspx?p=s&a=Software;1
License: Proprietary (free to EPA)
Version: 5.1 (2005)

"The Groundwater Modeling System (GMS) provides an integrated and comprehensive computational environment for simulating subsurface flow, contaminant fate/transport, and the efficacy and design of remediation systems."

"GMS integrates and simplifies the process of groundwater flow and transport modeling by bringing together all of the tools needed to complete a successful study. GMS provides a comprehensive graphical environment for numerical modeling, tools for site characterization, model conceptualization, mesh and grid generation, geostatistics, and sophisticated tools for graphical visualization."

“Several types of models are supported by GMS. The current version of GMS provides a complete interface for the codes MODAEM, FEMWATER, MODFLOW2000, MODPATH, MT3D, RT3D, ART3D, SEAM 3D, NUFT, UTCHEM, FACT and SEEP2D. The parameter estimation codes PEST and UCODE are also supported. Additional tools and interfaces for models are being designed in an on-going development process so stay tuned for more features.”

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3. Where do I find documentation regarding the theoretical background of WhAEM?

WhAEM is a single aquifer Dupuit-Forchheimer model based on the analytic element method (AEM). The theoretical foundations of this method are found in the text "Groundwater Mechanics" by O.D.L. Strack (1989, Prentice Hall) and in the text "Analytic Element Modeling of Groundwater Flow" by H.M. Haitjema (1995, Academic Press). Additional readings are found in the peer reviewed literature since 1981 and on various web sites by AEM researchers. Also, See FAQ question 1.
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4. Are newer WhAEM versions backward compatible?

After installing a newer version of WhAEM you can read your current (old) database files (***.whm**). As soon as the new version accesses an old database file you will get a message that the database must be modified. When confirming (clicking yes) the database will automatically be modified to the format necessary for the newer version. However, once modified, you cannot access that file anymore with the old version of WhAEM.
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5. Why does WhAEM not have a save command?

WhAEM is a database program. This means that data management does not occur in RAM to be saved to disk by an explicit user action (clicking on Save), but any data modifications in WhAEM are immediately implemented in a database, which resides on the disk. This is similar to the way the database program Access or the financial management program Quicken works. Consequently, WhAEM has no *Save* option, but you will find a *Make Duplicate Database…* option on the *Project* menu. If you want to make changes in a model and not loose the current model, you must make a duplicate database under a new name before you make your modifications. The database on disk is also referred to as the *project file* and has the extension **.whm**. The graphical user interface (GUI) uses various additional files to communicate with the Solver. For each project (file) you should also define a unique *Base Filename*, which is done on the *Project Settings* dialog box *(Project>Project Settings)*.
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6. Why are my base maps not lining up?

After entering a set of base map files (vector or raster) on the project menu, two post stamp size maps occur on two sides of the map window in WhAEM (after a zoom to extent). This is most likely due to the fact that the base map files represent maps in two different UTM zones. To fix this, project the maps from one of the two zones into the other zone or project both sets of maps into state plane coordinates. This may be done by use of the *Reproject Basemaps* option on the *Tools* menu or using GIS software.
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7. How do I apply areal recharge due to precipitation?

Areal recharge is defined as the net amount of water (precipitation minus runoff and minus evapotranspiration) that enters the aquifer per unit time and per unit area. In WhAEM the units are in meters per day or feet per day. The recharge rate may vary over the model domain. You should think in terms of a background recharge rate, applied over the entire model area, and local adjustments to it. After the near-field and far-field line-sinks have been entered you will have a good idea of the extent of the model area. Place a big (e.g. rectangular) inhomogeneity over the entire model area with the background recharge rate and the (effective) porosity as the only input parameters. The porosity will default to the one specified on the *Aquifer* tab (*Models>Settings>Aquifer*). You can use four big line elements to define the area. Make sure you include all line-sinks (you cannot make the area too large). Next, add or subtract recharge in areas where you want a different recharge rate. You do this by defining inhomogeneity domains with the recharge set to what you want to add or subtract.

Note 1: When entering inhomogeneity domains with different hydraulic conductivity or aquifer base elevation, you can add or subtract recharge at the same time.

Note 2: The recharge specified for inhomogeneity domains are cumulative; in nested domains these recharge rates will be added.

Note 3: When nesting inhomogeneities the hydraulic conductivity and porosity settings on the inside inhomogeneity redefine those parameters.

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8. How do I represent wide streams, lakes or wetlands with line-sinks?

This may depend on where the surface water feature occurs. In the near-field line-sinks should be placed along the perimeter of the surface water feature, whether a lake or a stream. In the farfield streams and small lakes or wetlands may be represented with line-sinks at their centers, while larger lakes and wetlands may still require a few line-sinks around their perimeter. The idea for the near-field lakes or wetlands is that groundwater will enter the lake (wetland) near its boundary, thus that is where the line-sinks should be. In the event that the lake, wetland or stream bottom offers resistance to groundwater inflow or outflow, line-sinks with resistance should be used. As a rule of thumb, the line-sink width should be set to the square root out of the product of the aquifer transmissivity and the bottom resistance. In case this width is more than the stream width, the line-sink may be placed at the center of the stream and be given the actual stream width. These guidelines are also contained in the WhAEM Help system, press F1 when the *Linesink String Properties* dialog is open and then click on the link “Creating Linesinks in the Near field and Far field.”

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9. What does "Treat as far-field" mean on the Linesink String Properties dialog?

The area of interest in your model must be surrounded by surface water features (line-sinks) that define the "far-field" hydrology in the model. These line-sinks on the perimeter of your model area perform a similar function as the conditions specified on the perimeter of a finite difference grid. Line-sinks in the far-field receive water or infiltrate water based on arbitrary conditions outside the model domain. Consequently, these line-sinks do not realistically represent surface water and groundwater interactions and should not be given a bottom resistance, width and depth parameter. Instead, they should simply maintain the specified head, regardless of the amount of water that must be extracted or infiltrated. By checking the box "Treat as "far-field" on the linesink dialog box all fields, except for the heads, are disabled. In summary, all line-sinks on the outside of the model domain must be checked as "Treat as "far-field"". For further reading on the matter see "Analytic Element Modeling of Groundwater Flow" by H. M. Haitjema, Academic Press, 1995, Section 5.1.1 page 207.

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10. How can WhAEM produce three-dimensional pathlines?

While WhAEM is a so-called Dupuit-Forchheimer model, which uses two-dimensional flow equations, the third (vertical) component of flow can be estimated from continuity considerations. In case the aquifer has a constant transmissivity and a constant recharge rate the vertical component of flow in WhAEM appears to be the same as found from a truly three-dimensional model. In all other cases the vertical component of flow in WhAEM is approximate. For most cases of regional flow the approximation is very accurate. For further reading on the matter see "Analytic Element Modeling of Groundwater Flow" by H. M. Haitjema, Academic Press, 1995, Section 3.5 (page 140).

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11. What is the “Starting Elevation” on the Well Properties Other tab?

Since WhAEM traces pathlines in three-dimensions, a *Starting Elevation* must be defined for each pathline trace. It is recommended that for capture zone delineation you set the *Starting Elevation* equal to the aquifer bottom. In this manner the pathline trace will remain along the aquifer bottom, providing for the largest capture zone. Higher *Starting Elevations* may result in shorter pathlines as a (hypothetical) water particle is back traced in time to the point where it entered the aquifer at the water table (or aquifer top). Remember that in a Dupuit-Forchheimer model, like WhAEM, partially penetrating wells are treated as fully penetrating. Consequently, you can define a *Starting Elevation* at the aquifer bottom even though in reality the well screen may not reach that deep.

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12. Why do I get different pathlines when at different zoom levels?

WhAEM uses a numerical integration process, which is part of the GFLOW1 Solver, for tracing pathlines. The step size is fixed and defined as a percentage (2%) of the horizontal size of the window setting in WhAEM. Consequently, for a large window (zoomed out) the step size is large and the pathline trace may be inaccurate. This is often evident from the hooky nature of the trace near the well. There are two remedies: (a) zoom in to the area where you expect the capture zone to occur or (b) select a smaller step size on the *Model>Settings>Tracing* tab. The small window option is the most reliable. If you need to have a larger window, you may first trace in a zoomed in window and after the capture zone is complete zoom out to the desired window. This will maintain tracing accuracy (unless you do a new trace, of course).

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13. Steady State versus Transient flow modeling?

WhAEM is a steady state model. Capture zone delineation is usually performed with a steady state model, since time dependent capture zones would be of little regulatory value. If aquifers respond fast to transient forcing (pumping periods), it is best to specify the maximum pumping rates (when the wells are running). However, if the aquifer responds slowly to the pumping periods, it may be more reasonable to specify average pumping rates. Similarly, test point values should be used for conditions of maximum pumping or averages may be more appropriate. The issue of fast or slow responding aquifers is addressed quantitatively in “Analytic Element Modeling of Groundwater Flow” by H.M. Haitjema (1995, Academic Press, section 5.3.7).

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14. Are there “rules of thumb” for an acceptable level of model error?

When calibrating to heads the distribution of the heads may be more meaningful than a root mean square error (RMSE). Look for about as many heads that are too high as that are too low. You do not want to see trends in the errors (all high heads in one area) and one should only look for errors in the near field (area of interest). What errors in the head can be accepted? Quite frankly, that is not easily answered since we are not modeling to predict heads! The modeling objective, in the context of source water assessment, is to predict the capture zone for one or more wells. Strictly speaking, therefore, you should calibrate against observed capture zones, but those don't exist (this is why you are modeling in the first place). On the other hand, a good match of the heads (whatever that means) does not in any way guarantee a good capture zone. For instance, the aquifer porosity has no effect on your steady state solution in terms of heads or flows. However, the length of the "time of travel" capture zone will depend greatly on the aquifer porosity.

The following approach is recommended:

1) Within the limits of the quality of your data establish a model with relatively low heads that you still consider plausible (more modeled heads too low than too high).
2) Next develop a model with relatively high heads (more modeled heads too high than too low). Again, this model should in your judgment still be plausible, although not the most likely model.
3) These "bounding solutions" will yield some bounding ratios of aquifer recharge over aquifer conductivity. Within this range of recharge/conductivity ratios determine the most likely upper bound and lower bound for the recharge rate and the conductivity itself. You may look at baseflow in streams in the model area to get a feel for the recharge rates, which in turn will yield the conductivities based on the modeling results: recharge /conductivity ratios.
4) Develop several models for bounding values of recharge and conductivity and trace streamlines from the well(s) to get the time of travel capture zones.
5) Now you will know if the errors are acceptable. If the capture zones are not too different, or if the differences in capture zones are inconsequential (e.g. all avoid an industrial area) your model accuracy is "acceptable." If the spread in capture zones is of concern you know that you need more reliable data (better stream elevations, recharge rates and conductivity values).

The procedure outlined above leaves a lot of room for interpretation by the modeler, but that is the reality of data uncertainty. However, the type of sensitivity analysis outlined above will potentially lead to the most robust wellhead protection program for a well or well field.

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Last Update: June 2005
By Stephen Kraemer