

APPLIED GROUNDWATER MODELING

Simulation of Flow and
Advective Transport

Second Edition

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The front cover image is provided courtesy of Schlumberger Water Services. The image represents a uniform grid for a multi-layer finite-difference MODFLOW model and was produced using the software Visual MODFLOW Flex. Colors at the top of the image represent changes in land surface elevation; colors in the bottom layers represent geologic variability. The back cover graphic is a word cloud created using all text contained in Chapters 1–12. Word-cloud graphics included with the introductory sections of the book consist of text contained in each section. All word clouds were generated using Wordle, created by Jonathon Feinberg (www.wordle.net).

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at a military base in North Carolina (Clement, 2011). Hindcasting applications are "uniquely challenging" (Clement, 2011) because it is not possible to collect additional observations to augment the existing historical dataset, which is often meager.

1.3.2 Interpretative Models

Interpretive models include those used as: (1) *engineering calculators* that quickly give an answer to a specific engineering question; (2) *screening models* that help the modeler develop an initial understanding of a groundwater system and/or test hypotheses about the system; (3) *generic models* that explore processes in generic hydrogeologic settings. Models used as engineering calculators and generic models usually are not calibrated. Screening models may or may not be calibrated.

An example application of an interpretive model as an engineering calculator is the use of analytical and numerical models to calculate aquifer parameters from drawdown data obtained in an aquifer (pumping) test. Analytical models and sometimes numerical models are used as engineering calculators to verify new codes (Section 1.6).

A screening model vets a conceptual model or tests hypotheses about the flow system. A screening model might help in designing a more complex numerical model. For example, Hunt et al. (1998) developed a two-dimensional AE model as a screening model to develop boundary conditions for a three-dimensional FD model. Interpretive models also are used to conceptualize system dynamics and provide general insights into controlling parameters or processes at a field site. For example, during a major oil spill from a damaged well in the Gulf of Mexico, Hsieh (2011) quickly developed an interpretive MODFLOW model (adapted to simulate flow in a petroleum reservoir) to determine if measured shut-in pressure in the damaged well was indicative of a potential future catastrophic rupture of the capped well. The results were used to make the decision not to uncap the well to reduce reservoir pressure, which proved to be the correct course of action.

Generic models are interpretive models applied to idealized groundwater systems. Generic models were used in the early days of numerical modeling of groundwater flow and continue to be useful. For example, Freeze and Witherspoon (1967) and Zlotnik et al. (2011) used two-dimensional generic models to study the effects of heterogeneity on regional groundwater flow in cross section. Woessner (2000) and Sawyer et al. (2012) used generic models to study exchange between groundwater and streams at the aquifer/stream interface (the hyporheic zone). Sheets et al. (2005) used generic models to assess the effect of pumping near regional groundwater divides.

1.4 LIMITATIONS OF MODELS

Groundwater models are simplifications of reality and thus are limited by underlying simplifying approximations as well as by nonuniqueness and uncertainty (Chapters 9