“Effective Groundwater Model Calibration, with Analysis of Data, Sensitivities, Predictions, and Uncertainty”
By Mary C. Hill and Claire R. Tiedeman
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Corrections and additional references

Page	Correction
8	Section 1.3.1, line 1 and 2. Reword to “…produce model predictions that are accurate enough to be useful in assessing the consequences…”
28	On line 7, the variable defined is the residual. Omit the word “weighted”.
29	The more common form of the maximum-likelihood objective function is obtained by substituting in the maximum likelihood estimate of σ^2, which equals $(\mathbf{e}^T \boldsymbol{\omega}\, \mathbf{e})/n$. Making this substitution into equation 3.3 and eliminating constant terms yields $S'(\mathbf{b}') = n \times \ln [(\mathbf{e}^T \boldsymbol{\omega}\, \mathbf{e})/ n]$. Here, n = NOBS+NPR.
33	First line of second paragraph. “models” should be “layers”.
33	The last sentence of the third paragraph should read “The variance of the error can be derived from geostatistical arguments; see, for example the option available in PEST (Doherty, 2005).”
50	In Equation 4.6, on the right-hand-side, the bracket should precede the summation so that the summation is completed before the square root is taken.
99	AICc, AIC, and BIC (equations 6.3 and 6.4) are more commonly calculated with $S'(\mathbf{b}') = n \times \ln [(\mathbf{e}^T \boldsymbol{\omega}\, \mathbf{e})/ n]$, where n = NOBS+NPR. See also the correction for page 29.
102-103	In figures 6.1 and 6.2, the standard error of the regression is used to label the vertical axes labeled “Weighted residuals”. If the weighted residuals are independent and normally distributed, only about 5 of 100 weighted residuals would be exceed two standard errors in absolute value. About 3 of 1000 would exceed three standard errors.
157	The critical values for total and intrinsic model nonlinearity measure are: Greater than 1.0, highly nonlinear 0.9 to 1.0, nonlinear 0.01 to 0.9, moderately nonlinear Less than 0.01, effectively linear
167	The definition of the identity matrix following equation 8.6 should be “(diagonal elements equal 1.0; others are 0.0)”
172	The reference for Good (2001) is listed below in this document.
191	In the middle of the page the definition of sensitivity should read as follows: “…with respect to the parameters, calculated at the optima…”
206	Toward the bottom of the page, the first line of the Problem should refer to Question 4 instead of 3.
208	Second line from the bottom of the page should refer to Question 5 instead of 4.
212	Third line from the bottom of the page should refer to Question 5 instead of 4.

Page	Correction
358	The first equation should be "$1/(sd_1^2 + sd_2^2 + sd_3^2 + \ldots)$"
392	Equation C.1. The first X should be the same as the other X's in this equation.
414	The following reference is missing Good PI (2001). Resampling Methods- a practical guide to data analysis. Birkhauser.
408	For Barlebo et al. (1996), the order of the two editors should be reversed and the name of the second editor should be spelled Heijde.
420	For Poeter et al. (2005), Christensen S is the fifth author

Additional References

While over 300 references are cited in the book, the topics covered have been the subject of considerable activity over more than three decades, and many references are not included. We do not expect to maintain a complete reference list for the topics of interest, but as we become aware of publications that might be helpful to readers of the book, we will include them here with an indication of their relevance.

Beven, Keith, Freer, Jim (2001). Equifinility, data assimilation, and uncertainty estimation in mechanistic modelling of complex environmental systems using the GLUE methodology. Journal of Hydrology, 249: 11-29. Related to references to Beven and Binley (1992) and Binley and Beven (2003), pages 11, 140,187, and 188.

Cirpka, O. A., C. M. Bürger, W. Nowak, M. Finkel (2004). Uncertainty and data worth analysis for the hydraulic design of funnel-and-gate systems in heterogeneous aquifers, Water Resour. Res., 40, W11502, doi:10.1029/2004WR003352. Includes the effects of small-scale heterogeneity.

Dai, Z., Samper, J. (2006). Inverse modeling of water flow and multicomponent reactive transport in coastal aquifer systems, Journal of Hydrology, 327(3-4), 447-461. Additional example for Section 9.2.7.

Gaganis, P., Smith, L. (2006). Evaluation of the uncertainty of groundwater model predictions associated with conceptual errors: A per-datum approach to model calibration, Advances in Water Resources, 29(4), 503-514. Relates to prediction uncertainty in Chapter 8 and Guideline 14, and discussion of model error uncertainties in Guideline 6.

Good PI (2001). Resampling Methods- a practical guide to data analysis. Birkhauser. [referenced on page 172 of the book.]

Kunstmann, H., W. Kinzelbach, and T. Siegfried, Conditional first-order second-moment method and its application to the quantification of uncertainty in groundwater modeling, Water Resour. Res., 38(4):10.1029/2000WR000022, 2002. Example of first-order-second moment application to a ground-water model and comparison with Monte Carlo analysis.

Kunstmann, H, Kastens, M. (2006) Determination of stochastic well head protection zones by direct propagation of uncertainties of particle tracks, Journal of Hydrology, 323(1-4), 215-229. Example for Guideline 14: comparison of using inferential statistics and Monte Carlo methods to quantify uncertainty in predicted capture zones.

Linde, N., Finsterle, S, Hubbard, S (2006). Inversion of tracer test data using tomographic constraints, Water Resour. Res., 42, W04410, doi:10.1029/2004WR003806. Additional example for Table 11.2.

Mugunthan, P., and C. A. Shoemaker (2006). Assessing the impacts of parameter uncertainty for computationally expensive groundwater models, Water Resour. Res., 42, W10428, doi:10.1029/2005WR004640, A computationally efficient global optimization method and alternative to Monte Carlo for quantifying prediction uncertainty. Relates to Section 5.2 and Guideline 14.

Pappenberger, F., K. J. Beven (2006). Ignorance is bliss: Or seven reasons not to use uncertainty analysis, Water Resour. Res., 42, W05302, doi:10.1029/2005WR004820. Discussion of arguments against conducting uncertainty analysis, and why the arguments are untenable.

Sanz, E. and Voss, C.I., 2006, Inverse modeling for seawater intrusion in coastal aquifers: Insights about parameter sensitivities, variances, correlations and estimation Procedures derived from the Henry problem: Advances in Water Resources v. 29, no. 3, p. 439-457.

Šimunek, J., and Nimmo, J.R., 2005, Estimating soil hydraulic parameters from transient flow experiments in a centrifuge using parameter optimization technique: Water Resources Research, v. 41, no. 4, doi:10.1029/2004WR003379.

Sun, A. Y., S. L. Painter, and G. W. Wittmeyer (2006), A constrained robust least squares approach for contaminant release history identification, Water Resour. Res., 42, W04414, doi:10.1029/2005WR004312. Additional example for Section 9.2.2.

Tiedeman, C.R., Hill. M.C. (2006). Tools for ground-water flow and transport model calibration, sensitivity analysis, error and uncertainty evaluation, and assessment of prediction data needs, in Thangarajan, M., ed., Groundwater: Resource Evaluation, Augmentation, Contamination, Restoration, Modeling and Management: New Delhi, Capital Publishing, p. 237-282. Relates to section 9.2.

Vermeulen, P. T. M., C. B. M. te Stroet, A. W. Heemink (2006). Model inversion of transient nonlinear groundwater flow models using model reduction, Water Resour. Res., 42, W09417, doi:10.1029/2005WR004536. Alternative methods for inverse modeling of computationally demanding models. Relates to Section 15.1.