DEPARTMENT OF HEALTH

# Groundwater Model Calibration Policy

SOURCE WATER PROTECTION

Calibrated groundwater flow models may be used to address many hydrologic problems. In the Source Water Protection (SWP) program, our primary use of flow models is the generation of well capture zones, also known as wellhead protection areas. Model calibration is a procedure that compares the results of a model based on estimated input values to measured or known values. Because the natural world is complex both in properties and processes, models almost always have more unknown values than known values. Furthermore, the known values are typically not sufficient to constrain the model to one unique solution and often suffer from questions of data quality or temporal validity. A model is therefore a necessary simplification of the real world used to answer practical questions. Due to the non-unique nature of most models, there can be "families" of models that fit the available information equally well that provide different answers. The "best" calibrated model will ideally:

- Be based on the strongest conceptual model
- Utilize the information contained in available known values
- Avoid inappropriate simplifications and complications
- Be sufficiently discretized in space
- Have manageable run times
- Adequately address the objective of the model

The most common approach for judging how well a model fits reality is through history matching. As a matter of practice, history matching refers to modifying the model input data to more closely match field measurements like water elevation (head) and/or flux. There are different quantitative measures that are used to show the accuracy of the history match calibration, some of which are listed below. However, a good fit does not necessarily mean a model is well-calibrated or appropriate for well capture zone delineation. The match is acceptable only if the parameters and assumptions used to obtain the fit are reasonable and, in the case of well capture zone analysis, the gradient and direction of groundwater flow are reasonably simulated within the area of interest. Therefore, calibration also includes an evaluation of "hydrogeologic reasonableness", wherein knowledge about the groundwater system and processes are considered. If no reasonable parameters can be found it is likely that the conceptual model is incorrect. Generally, models may fail calibration due to an unsatisfactory quantitative history match, unreasonable parameter values, and/or they do not conform to the strongest conceptual model. The logical endpoint of calibration is an "appropriate model", which balances sophistication and realistic representation (i.e. an acceptable fit to observations and reasonable parameters and assumptions) with the resources and time available.

## SWP Model Calibration Guidelines

SWP will use a multiple lines of evidence approach when deciding if calibration of a groundwater flow model is "appropriate" as defined above. The following are a set of general guidelines and goals.

## Qualitative Comparison

- A plot of the observed and simulated potentiometric surfaces mimics the important aspects of the flow system, such as magnitude and direction, and allows for a quick visual assessment of the model simulation.
- A spatially plotted map of residuals shows where simulated heads are too high or too low, with the goal of a random areal distribution and, ideally, low residuals near the well capture zone.
- Scatter plots of calibration targets versus simulated values show potential model bias that might be addressed by adjusting values for recharge or hydraulic conductivity, for example.
- An assessment of the general flux through the model should be evaluated at surface water features and/or the recharge values. If there are known values, such as a gauging station, then typically a simulation within an order of magnitude is acceptable. Otherwise literature values (e.g. *A regression model to estimate regional ground water recharg*e) or professional judgement (i.e. an intermittent stream should not have the flow rate of the Mississippi River and recharge should not be on the order of a tropical rainforest) should be used.

## Quantitative Comparison

- Residual Mean Error should be minimized, approaching a value of 0.
- Normalized/Scaled Residual Standard Deviation (Residual Standard Deviation divided by Range of Observations) should be less than 10%
- Normalized/Scaled Root Mean Square Error (Root Mean Square Error divided by Range of Observations) should be less than 10%

### References

Anderson, M.P., Woessner, W.W., Hunt, R.J., 2015, Applied Groundwater Modeling—Simulation of flow and advective transport: Academic Press, Inc., San Diego, Calif., 630 p.

ASTM D5447-17, Standard Guide for Application of a Numerical Groundwater Flow Model to a Site-Specific Problem, ASTM International, West Conshohocken, PA, 2017, www.astm.org

ASTM D5490-93(2014)e1, Standard Guide for Comparing Groundwater Flow Model Simulations to Site-Specific Information, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM D5981 / D5981M-18, Standard Guide for Calibrating a Groundwater Flow Model Application, ASTM International, West Conshohocken, PA, 2018, www.astm.org

Environmental Simulations Inc., 2017, Guide to Using Groundwater Vistas, Leesport, PA, 447 p.

Lorenz, D.L., Delin, G.N., 2006, A Regression Model to Estimate Regional Ground Water Recharge, Groundwater, Volume 45, Issue 2.

Reilly, T.E., and Harbaugh, A.W., 2004, Guidelines for evaluation ground-water flow models: U.S. Geological Survey Scientific Investigations Report 2004-5038, 30 p.

Minnesota Department of Health
Source Water Protection
625 Robert St. N
St. Paul, MN 55164
651-201-4700
www.health.state.mn.us
12/03/2018