Appendix C <u>GROUNDWATER AND SOLUTE TRANSPORT MODELS</u>

There are countless groundwater and solute transport models available from public and private institutions. Any attempt to list available models will necessarily be incomplete and obsolete before it is finished. Rather than attempt to list available models and negotiate the hazards of copyright and compatibility, this appendix offers a partial bibliography of published modeling information that has proven to be useful over the years. This is by no means a complete list, but these are among the documents we turn to when planning a modeling project. Potential applicants are strongly encouraged to consult with DEQ prior to beginning a modeling project to support an application, to confirm that the models chosen are appropriate and acceptable.

Alexander, M., S.J. Berg, and W.A. Ilman. 2010. Field study of hydrogeologic characterization methods in a heterogeneous aquifer. *Ground Water*, vol. 49, no. 3, pp. 365-382.

Alexander, R.B., J.K. Bohlke, E.W. Boyer, M.B. David, J.W. Harvey, P.J. Mulholland, S.P. Seitzinger, C.R. Tobias, C. Tonito, and W.M. Wollheim. 2009. Dynamic modeling of nitrogen losses in river networks unravels the coupled effects of hydrological and biogeochemical processes. *Biogeochemistry*, Vol. 93, pp. 91-116.

Anderson, M.P. and W.W. Woessner, 1992. *Applied ground water modeling: Simulation of flow and advective transport*. Academic Press. 381 p.

Azadpour-Keeley, A., B.R. Faulkner, and J.S. Chen. 2003. *Movement and longevity of viruses in the subsurface*. EPA/540/S-03/500. 25 p.

Aziz, C.E., C.J. Newell, J.R. Gonzales, P. Haas, T.P. Clement, and Y. Sun. 2000. *BIOCHLOR: Natural attenuation decision support system user's manual, version 1.0.* EPA/600/R-00/008.

Batu, V. 1988. Contaminant plume analysis using the hydrodynamic dispersion stream function (HDSF) concept. *Ground Water*, Vol. 26, no. 1, pp. 71-77.

Batu, V. and M.T. van Genuchten. 1990. First- and third-type boundary conditions in twodimensional solute transport modeling. *Water Resources Research*, Vol. 26, no. 2, pp. 339-350.

Bear, J., M.S. Beljin, and R.R. Ross. 1992. Fundamentals of ground-water modeling. EPA/540/S-92/005

Bekins, B.A., E. Warren, and E.M. Godsy. 1998. A comparison of zero-order, first-order, and monod biotransformation models. *Ground Water*, Vol. 36, no. 2. pp. 261-268.

Beljin, M., R.R. Ross, and S.D. Acree. 2014. *3PE: A tool for estimating groundwater flow vectors*. EPA/600/R-14/273. 60 p.

Bennett, G.D. 1989. Introduction to ground-water hydraulics: A programed text for selfinstruction. USGS Water-Resources Investigation TWI 3-B2.

Bentall, R. 1963. *Methods of determining permeability, transmissibility and drawdown*. USGS Water Supply Paper 1536-I

Bohne, K., C. Roth, F.J. Leij, and M.T. van Genuchten. 1993. Rapid method for estimating the unsaturated hydraulic conductivity from infiltration measurements. *Soil Science*, Vol. 155, no. 4, pp. 237-244

Braunsfurth, A.C. and W. Schneider. 2008. Calculating ground water transit time of horizontal flow through leaky aquifers. *Ground Water*, Vol. 46, no. 1, pp. 160-163

Buerge, I.J., H.R. Buser, M. Kahle, M.D. Muller, and T. Poiger. 2009. Ubiquitous occurrence of the artificial sweetener acesulfame in the aquatic environment: An ideal chemical marker of domestic wastewater in groundwater. *Environmental Science & Technology*, Vol. 43, pp. 4381-4385

Butler, J.J. Jr., X. Zhan, and V.A. Zlotnik. 2007. Pumping-induced drawdown and stream depletion in a leaky aquifer system. *Ground Water*, Vol. 45, no. 2, pp. 178-186

Chapuis, R.P. and R. Chesnaux. 2000. Travel time to a well pumping an unconfined aquifer without recharge. *Ground Water*, Vol. 44, no. 4, pp. 600-603

Chesnaux, R., J.W. Molson, and R.P. Chapuis. 2005. An analytical solution for ground water transit time through unconfined aquifers. *Ground Water*, Vol. 43, no. 4, pp. 511-517

Chong-Xi, C., H. Li-Tang, and W. Xu-Sheng. 2006. Analysis of steady ground water flow toward wells in a confined-unconfined aquifer. *Ground Water*, Vol. 44, no. 4, pp. 609-612

Clement, T.P., Y. Sun, B.S. Hooker, and J.N. Petersen. 1998. Modeling multispecies reactive transport in ground water. *Ground Water Monitoring*, Spring, 1998. pp. 79-92

Cooley, R.L. and R.L. Naff. 1990. *Regression modeling of ground-water flow*. USGS Techniques of Water-Resources Investigations 30B4, 241 p.

Cooper, H.H. and C.E. Jacob. 1953. *A generalized graphical method of evaluating formation constants and summarizing well-field history*. USGS Ground Water Notes 7. 14 p.

Devlin, J.F. and C.D. McElwee. 2007. Effects of measurement error on horizontal hydraulic gradient estimates. *Ground Water*, Vol. 45, no. 1, pp. 62-73

Di Matteo, L. and W. Dragoni. 2005. Empirical relationships for estimating stream depletion by a well pumping near a gaining stream. *Ground Water*, Vol. 43, no. 2, pp. 242-249

Doble, R.C., C.T. Simmons, and G.R. Walker. 2009. Using MODFLOW 2000 to model ET and recharge for shallow ground water problems. *Ground Water*, Vol. 47, no. 1, pp. 129-135

Driscoll, F.G. 1986. Groundwater and wells, second edition. Johnson Screens, St. Paul. 1089 p.

Edington, D. and E. Poeter. 2006. Stratigraphic control of flow and transport characteristics. *Ground Water*, Vol. 44, no. 6, pp. 826-831

Faulkner, B.R., W.G. Lyon, F.A. Khan, and S. Chattopadhyay. 2002. *Predicting attenuation of viruses during percolation in soils: 1. Probabilistic model.* EPA-600-R-02-051a. 43 p.

Faust, C.R. and J.W. Mercer. 1980. Ground-water modeling: Numerical models. *Ground Water*, Vol. 18, no. 4, pp. 395-409

Ferris, J.G., D.B. Knowles, R.H. Brown, and R.W. Stallman. 1962. *Theory of aquifer tests*. USGS Water Supply Paper 1536-E

Festger, A.D. and G.R. Walter. 2002. The capture efficiency map: The capture zone under time-varying flow. *Ground Water*, Vol. 40, no. 6, pp. 619-628

Fetter, C.W. 1994. Applied hydrogeology, third edition. Prentice-Hall, 691 p.

Fleckenstein, R.G., J.H. Niswoger, and G.E. Fogg. 2006. River-aquifer interactions, geologic heterogeneity, and low-flow management. *Ground Water*, Vol. 44, no. 6, pp. 837-852

Foglia, L., S.W. Mehl, M.C. Hill, P. Perona, and P. Burlando. 2007. Testing alternative ground water models using cross-validation and other methods. *Ground Water* Vol. 45, no. 5, pp. 627-641

Franke, O.L., T.E. Reilly, and G.D. Bennett. 1987. *Definition of boundary and initial conditions in the analysis of saturated ground-water flow systems- an introduction*. USGS Techniques in Water Resources Investigations 3-B5

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall. 624 p.

Frind, E.O., J.W. Molson, and D.L. Rudolph. 2006. Well vulnerability: A quantitative approach for source water protection. *Ground Water*, Vol. 44, no. 5, pp. 732-742

Gerke, H.H. and M.T. van Genuchten. 1993. A dual-porosity model for simulating the preferential movement of water and solutes in structured porous media. *Water Resources Research*, Vol. 28, no. 2, pp. 305-319

Gilbert, R.O. 1987. *Statistical methods for environmental pollution monitoring*. Van Nostrand Reinhold, New York. 320 p.

Glover, R.E. 1964. Ground-water movement. USBR Engineering Monograph 31

Goldberg, S. 1995. Adsorption models incorporated into chemical equilibrium models. *Soil Science Society of America Journal Special Publication* 42, pp. 75-95

Goldberg, S., L.J. Criscenti, D.R. Turner, J.A. Davis, and K.J. Cantrell. 2007. Adsorptiondesorption processes in subsurface reactive transport modeling. *Vadose Zone Journal*, Vol. 6, no. 3, pp. 407-435

Grubb, S. 1993. Analytical model for estimation of steady-state capture zones of pumping wells in confined and unconfined aquifers. *Ground Water*, Vol. 31, no. 1, pp. 27-32

Halford, K.J., W.D. Weight, and R.P. Schreiber. 2006. Interpretation of transmissivity estimates from single-well pumping aquifer tests. *Ground Water*, Vol. 44, no. 3, pp. 467-471

Hall, S.H., S.P. Luttrell, and W.E. Cronin. 1991. A method for estimating effective porosity and ground-water velocity. *Ground Water*, Vol. 29, no. 2, pp. 171-174

Hantush, M.S. 1964. Hydraulics of wells. Advances in Hydroscience, Vol. 1, pp. 282-432.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald. 2000. *MODFLOW-2000, The U.S. Geological Survey modular ground-water model- User guide to modularization concepts and the ground-water flow process.* USGS Open-File Report 00-92

Heath, R.C. 1983. Basic ground-water hydrology. USGS Water-Supply Paper 2220.

Hem, J.D. 1985. *Study and interpretation of the chemical characteristics of natural water*. USGS Water-Supply Paper 2254, 272 p.

Hemker, C.J. 1984. Steady groundwater flow in leaky multiple-aquifer systems. *Journal of Hydrology*, Vol. 72, pp. 355-374

Hughson, L., D. Huntley, and M. Razack. 1996. Cokriging limited transmissivity data using widely sampled specific capacity from pump tests in an alluvial aquifer. *Ground Water*, Vol. 34, no. 1, pp. 12-18.

Hvorslev, M.J. 1951. *Time lag and soil permeability in ground-water observations*. Waterways Experiment Station, USACE, Bulletin 36

Keely, J.F. and C.F. Tsang. 1983. Velocity plots and capture zones of pumping centers for ground-water investigations. *Ground Water*, Vol. 21, no. 6, pp. 701-714

Knox, R.C., D.A. Sabatini, and L.W. Canter. 1993. *Subsurface transport and fate processes*. Lewis Publishers. 430 p.

Kool, J.B., J.C. Parker, and M.T. van Genuchten. 1987. Parameter estimation for unsaturated flow and transport models- A review. *Journal of Hydrology*, Vol. 91, pp. 255-293

Kruseman, G.P. and N.A. DeRidder. 1994. *Analysis and evaluation of pumping test data*. International Institute for Land Reclamation and Development.

Lohman, S.W. 1972. Ground-water hydraulics. USGS Professional Paper 708.

Lusk, M., G.S. Toor, and T. Obreza. 2021. *Onsite sewage treatment and disposal systems: Viruses.* University of Florida Extension SL351.

Lyon, W.G., B.R. Faulkner, F.A. Khan, S. Chattopadhyay, and J.B. Cruz. 2002. *Predicting attenuation of viruses during percolation in soils: 2. User's guide to the Virulo 1.0 computer model*. EPA/600/R-02/051b, 26 p.

Mayotte, J. 2016. *Virus fate and transport in groundwater. Organic matter, uncertainty, and cold climate.* University of Uppsala Dissertation, 71 p.

Mercer, J.W. and C.R. Faust. 1980. Ground-water modeling: Mathematical models. *Ground Water*, Vol. 18, no. 3, pp. 212-227

Meredith, E.L. and S.L. Kuzara. 2012. Identification and quantification of base flow using carbon isotopes. *Ground Water*, Vol. 50, no. 6, pp. 959-965

Molz, F.J., O. Guven, and J.G. Melville. 1983. An examination of scale-dependent dispersion coefficients. *Ground Water*, Vol. 21, no. 6, pp. 715-725

Molz, F.J., G. Oktay, J.G. Melville, I. Javandel, A.E. Hess, and F.L. Paillet. 1990. *A new approach and methodologies for characterizing the hydrogeologic properties of aquifers*. EPA/600/2-90/002, 235 p.

Newell, C.J., H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, and M.P. Suarez. 2002. *Calculation and use of first-order rate constants for monitored natural attenuation studies*. EPA/540/S-02/500

Nielsen, D.R., M.T. van Genuchten, and J.W. Biggar. 1986. Water flow and solute transport processes in the unsaturated zone. *Water Resources Research*, Vol. 22, no. 9, pp. 89-108

Razack, M. and D. Huntley. 1991. Assessing transmissivity from specific capacity in a large and heterogenous alluvial aquifer. *Ground Water*, Vol. 29, no. 6, pp. 856-861

Rehmann, L.L.C., C. Welty, and R.W. Harvey. 1999. Stochastic analysis of virus transport in aquifers. *Water Resources Research*, Vol. 35, no. 7, pp. 1987-2006

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

Rosenberry, D.O. and J.W. LaBaugh. 2008. *Field techniques for estimating water fluxes between surface water and ground water*. USGS Techniques and Methods 4-D2, 135 p.

Rowe, M.L. and S. Stinnett. 1975. *Nitrogen in the subsurface environment*. EPA-660/3-75-030. 42 p.

Schulze-Makuch, D. 2005. Longitudinal dispersivity data and implications for scaling behavior. *Ground Water*, Vol. 43. No. 3, pp. 443-457

Simpson, M.J., T.P. Clement, and F.E. Yeomans. 2003. Analytical model for computing residence times near a pumping well. *Ground Water*, Vol. 41, no. 3, pp. 351-354

Spiliotopolous, A. and C.B. Andrews. 2006. *Analysis of aquifer test data- MODFLOW and PEST*. MODFLOW and More 2006: Managing Ground-Water Systems

Taylor, R., A. Cronin, S. Pedley, J. Barker, and T. Atkinson. 2004. *The implications of groundwater velocity variations on microbial transport and wellhead protection- Review of field evidence*. FEMS Microbiology Ecology, 10 p.

Theis, C.V. 1935. *The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground water storage*. USGS Ground Water Notes 5, 10 p.

USEPA. 1991. *Wellhead protection strategies for confined-aquifer settings*. EPA/570/9-91-008, 183 p.

Van Genuchten, M.T. 1982. A comparison of numerical solutions of the one-dimensional unsaturated-saturated flow and mass transport equations. *Advances in Water Resources*, Vol. 5, pp. 47-55

Van Genuchten, M.T. 1981. Analytical solutions for chemical transport with simultaneous adsorption, zero-order production and first-order decay. *Journal of Hydrology*, Vol. 49, pp. 213-233

Weight, W.D. and J.L. Sonderegger. 2001. *Manual of applied field hydrogeology*. McGraw-Hill, 608 p.

Weldeyohannes, A.O., G. Kachanoski, and M. Dyck. 2018. Wastewater flow and pathogen transport from at-grade line sources to shallow groundwater. *Journal of Environmental Quality*, Vol. 47, pp. 1051-1057

Wheatcraft, S.W. 2000. Travel time equations for dispersive contaminants. *Ground Water*, Vol. 38, no. 4, pp. 505-509

Wosten, J.H.M. and M.T. van Genuchten. 1988. Using texture and other soil properties to predict the unsaturated soil hydraulic functions. *Soil Science Society of America Journal*, Vol. 52, pp. 1762-1770

Yates, M.V. and S.R. Yates. 1988. Virus survival and transport in ground water. *Water Science and Technology*, Vol. 20, no. 11/12, pp. 301-307