DRAINMOD:
A SIMULATION MODEL FOR SHALLOW WATER TABLE SOILS

R.W. Skaggs[1]

AUTHORS: [1] William Neal Reynolds and Distinguished University Professor, Biological and Agricultural Engineering Department, North Carolina State University, Campus Box 7625, Raleigh, NC 27695.

REFERENCE: *Proceedings of the 2008 South Carolina Water Resources Conference*, held October 14-15, 2008 at the Charleston Area Event Center

DRAINMOD was developed to simulate the performance of drainage and related water management systems (Skaggs, 1976, 1978, 1982, 1999). It is based on a water balance in the soil profile and predicts water table depths, soil water conditions, and drainage rates on a continuous basis. Input data include soil properties, crop parameters, drainage design parameters, weather and irrigation data. The model conducts a water balance on a hour-by-hour, day-by-day basis and calculates infiltration, ET, drainage, surface runoff, subirrigation, deep seepage, lateral seepage, water table depth and soil water status at each time step (Figure 1).

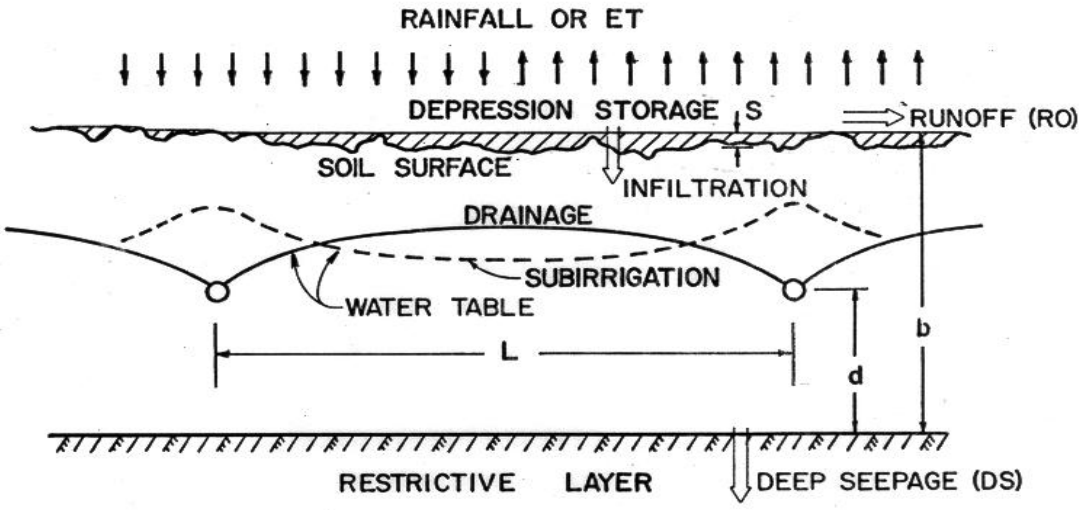

Figure 1. Schematic diagram of hydrologic processes simulated by DRAINMOD.

Detailed descriptions of the model logic and examples of its application have been given previously as cited above. The model, as originally developed, considered the water balance to be conducted at a point midway between parallel drains. The drainage algorithms in the model express drainage rates in terms of water table elevation (or depth) at the mid-plane between drains based on classical drainage theory. For such applications the Hooghoudt equation is used to predict drainage rates when the water table is below the surface, and an equation developed by Kirkham is applied when the profile is saturated and the surface is ponded. In fact the model is not limited to parallel drains and can be used for other drainage configurations, including no artificial drainage at all. Such applications require the input of parameters for subsurface drainage, and deep and lateral seepage components that describe the relationship between drainage rate and water table depth at the point on the landscape of interest. This may require calibration in some cases, but it is a valid and frequently used application of the model, especially for describing wetland hydrology.

DRAINMOD was originally developed to analyze the performance of drainage, subirrigation and controlled drainage systems. It has been widely used to fit system designs to local soil, site and climatological conditions to maximize yields and profits (e.g., Skaggs and Chescheir, 1999), and to determine design drainage

rates for the application of simple drainage equations for the eastern United States (Skaggs et al., 2006). It has also been used to quantify effects of design and management practices on drainage water quality (Skaggs and Gilliam, 1981). Breve et al. (1997) added algorithms to calculate a nitrogen balance in the soil profile. Youssef et al. (2005, 2006) developed and tested DRAINMOD-NII which simulates a complete nitrogen balance, as well as a carbon balance, allowing prediction of the effect of drainage system design and management on N losses in drainage water.

A salt balance was introduced in the model (Kandil et al., 1995) to simulate the effect of drainage design on soil salinity. This version (DRAINMOD-S) may be applied to determine the combined effects of drainage design and irrigation management on soil salinity, and crop yields in irrigated arid and semi-arid lands. The model can also be used to determine the effect of drainage design on the amount of waste water that can be treated by land application (Skaggs and Nassehzadeh-Tabrizi, 1982). It is also used to simulate the performance of drainage systems for lowering water tables for on-site residential waste treatment (septic) systems on poorly drained lands. Another application is the use of DRAINMOD to simulate the hydrology of stormwater wetland detention basins.

DRAINMOD has been applied to a wide range of issues related to wetland hydrology. It has been used to evaluate proposed criteria for defining wetland hydrology (Skaggs et al., 1994), both directly and indirectly to evaluate wetland hydrologic status of field sites (Hunt et al., 1995; Skaggs et al., 1995), as a tool for relating hydric soil field indicators to long-term hydrology (Vepraskas et al., 2004), and for quantifying the hydrologic requirements of wetland plant communities (Caldwell et al., 2008). The model has also been used for developing approximate, easy to use, methods for predicting lateral impact of drainage ditches and borrow pits on wetland hydrology (Skaggs et al., 2005, 2007).

DRAINMOD was developed to simulate conditions at the field scale. In recent years it has been extended to the watershed scale by inclusion of methods to route surface runoff from fields and to predict flow in drainage channels and receiving streams (Konyha and Skaggs, 1992; Fernandez et al., 2002, 2005, 2006, 2007). McCarthy et al. (1992); Amatya et al. (1997, 2004) and Amatya and Skaggs (2001) modified the model to describe the hydrology of drained forested lands on both field and watershed scales.

The presentation will discuss the philosophy of the development and testing of DRAINMOD and its various applications. The reliability of the application of a model, as with most other engineering tools, depends on the understanding and ability of the user, as well as the inherent strengths and limitations of the model. These concepts are discussed from the perspective of choosing and applying models for shallow water table soils.

LITERATURE CITED

Amatya, D. M. and R. W. Skaggs. 2001. Hydrologic modeling of a drained pine plantation on poorly drained soils. Forest Science, 47(1):103-114.

Amatya, D. M., G. M. Chescheir, G.P. Fernandez, R.W. Skaggs, and J.W. Gilliam. 2004. DRAINWAT-based Methods for Estimating Nitrogen Transport on Poorly Drained Watersheds. Trans. of *ASAE*, Vol. 43(3):677-687.

Amatya, D.M., R.W. Skaggs and J.D. Gregory. 1997. A watershed scale hydrologic model for drained forested land. *Journal of Agricultural Water Management 32:239-258*.

Breve, M.A., Skaggs, R.W., Parsons, J. E., and Gilliam, J.W. 1997. DRAINMOD-N, A nitrogen model for artificially drained soils. Transactions of the ASAE, Vol. 40(4):1067-1075.

Caldwell, P.V., M. J. Vepraskas, J. D. Gregory, R.W. Skaggs and R.L. Huffman. 2008. Quantifying the hydrologic requirements of wetland plant communities. Science, Submitted.

Fernandez, G.P., G.M. Chescheir, D. M. Amatya, and R.W. Skaggs. 2002. WATGIS: A GIS-based lumped parameter water quality model, Trans. ASAE, Vol. 45(3):593-600.

Fernandez, G.P., G.M. Chescheir, R.W. Skaggs and D. M. Amatya. 2005. Development and testing of watershed scale models for poorly drained soils. Trans. ASABE 48(2):639-652.

Fernandez, G.P., G.M. Chescheir, R.W. Skaggs, and D.M. Amatya. 2006. DRAINMOD-GIS: A lumped parameter watershed scale drainage and water quality model. Agricultural Water Management 81:77-97.

Fernandez, G. P., G.M. Chescheir, R.W. Skaggs, and D.M. Amatya. 2007. Application of DRAINMOD-GIS to a Lower Coastal Plain Watershed. Trans. ASABE 50 (2):439-447.

Hunt, W.F., Skaggs, R.W., Chescheir, G.M. and Amatya, D.M. 1995. Reference Simulations: Methods for Comparisons. In: K.L. Campbell (ed.) Versatility of Wetlands in the Agricultural Landscape. American Society of Agricultural Engineers, St Joseph, MI, pp 11-20.

Kandil, H.M., R.W. Skaggs, S. Abdel-Dayem, and Y. Aiad. 1995. DRAINMOD-S: Water management model for irrigated arid lands, crop yield and application. *Irrigation and Drainage Systems* 9:239-258.

Konyha, K. D. and R. W. Skaggs. 1992. A coupled field hydrology-open channel flow model: Theory. *Transactions of the ASAE* 35(5):1431-1440.

McCarthy, E.J., J.W. Flewelling and R.W. Skaggs. 1992. A hydrologic model for a drained forested watershed. *Journal of Irrigation and Drainage* 118(2):242-255.

Skaggs, R. W. 1976. Evaluation of drainage-water table control systems using a water management model. Proceedings of the

Third National Drainage Symposium, ASAE Publication 1-77, American Society of Agricultural Engineers, St. Joseph, MI, pp. 61-68.

Skaggs, R. W. 1978. A water management model for shallow water table soils. Technical Report No. 134. Water Resources Research Institute of the University of North Carolina, N. C. State University, Raleigh. 128 pp.

Skaggs, R. W. 1982. Field evaluation of a water management simulation model. *Transactions of the ASAE* 25(3):666-674

Skaggs, R.W. 1999. Drainage simulation models. In Skaggs and van Schilfgaarde (eds), Drainage for Agriculture, Monograph No.38, American Society of Agronomy, Madison, WI: 469-500.

Skaggs, R. W. and J. W. Gilliam. 1981. Effect of drainage system design and operation on nitrate transport. *Transactions of the ASAE* 24(4):929-934.

Skaggs, R. W. and A. Nassehzadeh-Tabrizi. 1982. Design and drainage systems for land treatment of wastewater. *ASCE, Journal of the Irrigation and Drainage Division* 108(IR3):196-211.

Skaggs, R.W. and G.M. Chescheir. 1999. Application of Drainage Simulation Models. In: Agricultural Drainage, (eds.) Skaggs and van Schilfgaarde, *Agronomy Monograph no. 38*, ASA, Madison, WI.

Skaggs, R. W., D. Amatya, R. O. Evans, and J. E. Parsons. 1994. Characterization and evaluation of proposed hydrologic criteria for wetlands. *Journal of Soil and Water Conservation* 49(5):501-510.

Skaggs, R.W., Hunt, W.F., Chescheir, G.M., and Amatya, D.M. 1995. Reference Simulations for Evaluating Wetland Hydrology. In: K.L. Campbell (ed.) Versatility of Wetlands in the Agricultural Landscape. American Society of Agricultural Engineers, St Joseph, MI, pp. 1-10.

Skaggs, R.W., G.M. Chescheir and B.D. Phillips. 2005. Methods to determine lateral effect of a drainage ditch on wetland hydrology. Trans. ASAE, 48(2):577-584.

Skaggs, R.W., M.A. Mohamed, and G.M. Chescheir. 2006. Drainage design coefficients for eastern United States. Agricultural Water Management 86: 40-49.

Skaggs, R.W., G.M. Chescheir and B.D. Phillips. 2007. Determination of lateral effects of borrow pits on hydrology of adjacent wetlands. CTE / NCDOT Final Report, N.C Department of Transportation, 1549 Mail Service Center, Raleigh, N.C. 27699, 85 pp.

Vepraskas, M.J., X. He, D.L. Lindbo, and R.W. Skaggs. 2004. Calibrating hydric soil field indicators to long-term wetland hydrology. Soil Sci. Soc. Am J. 68:1461-1469.

Youssef, M.A., R.W. Skaggs, G.M. Chescheir, and J.W. Gilliam. 2005. The nitrogen simulation model, DRAINMOD-NII. Trans ASABE, 48(2): 611-626.

Youssef, M.A., R. W. Skaggs, J.W. Gilliam and G.M. Chescheir. 2006. Field evaluation of a model for predicting nitrogen losses from drained lands. JEQ, 35: 2026-2042.