Agricultural Drainage Management Systems Task Force (ADMSTF)

A Partnership Group that Promotes and Implements Drainage Management Systems on Cropland in the Mississippi River Basin to Improve Water Quality of Drainage Flows.

James L. Fouss[1] and Michael Sullivan[2]

ABSTRACT

The Agricultural Drainage Management Systems (ADMS) Task Force was initiated during a charter meeting in the fall of 2002 by dedicated professional employees of Federal, State, and Local Government Agencies and Universities. The Agricultural Drainage Management (ADM) Coalition was established in 2003 by drainage industry officials, trade associations and non-government organizations. These two groups formed a working partnership to promote and implement drainage water management systems that can significantly improve the quality of drainage water flows from agricultural cropland. Earlier research had shown that a large percentage of the nitrate-nitrogen that migrates down the Ohio and Mississippi Rivers comes from surface and subsurface drainage discharge from agricultural cropland in the Midwest region. An initial primary goal of the partnership groups was to reduce the loss and transport of fertilizer nutrients, particularly nitrate-nitrogen, from drained agricultural croplands in the Midwestern States on a farm-by-farm basis. They installed and conducted field demonstrations for farmers to promote and encourage them to install and implement drainage water management practices (controlled-drainage) for both new drainage installations and by retrofitting their existing drainage systems with drainage outlet controls. Previous research that had been conducted at multiple locations to evaluate controlled-drainage systems documented that the decrease in nitrate-nitrogen loss in drainage discharge was almost directly proportion to the reduction in drainage outflow volume accomplished by installing control structures on the drainage outlets. A 50% reduction in drainage outflow and nitrate loss was a common research finding at most of these locations. The desired ultimate goal of the ADMSTF and ADMC partnership efforts was to implement drainage water management on a large enough scale (watershed-by-watershed) in the Midwest to decrease transport of excess nutrients through the Mississippi River drainage basin to the Gulf of Mexico. EPA and USGS had reported this source of nitrate-nitrogen as one of the major sources contributing to the persistent formation of the large hypoxic zone ("dead zone") in the Gulf of Mexico.

[1] Chair of ADMS Task Force, and Research Leader (Supervisory Agricultural Engineer), Soil & Water Research Unit, Agricultural Research Service (ARS), USDA, Baton Rouge, LA 70808; PH (225) 578-0743; FAX (225) 757-7728; email: james.fouss@ars.usda.gov

[2] Co-Chair of ADMS Task Force, and Mississippi River Basin Coordinator for the Natural Resources Conservation Service (NRCS), USDA, North Little Rock, AR 72116; PH: (501) 758-2544 (Ext. 115); email: Michael.Sullivan@wdc.usda.gov

Background and Need for Change in Agricultural Drainage Management Practices

In agricultural cropland areas where soil profiles have seasonal shallow water tables, a centuries old management practice has been to install subsurface (tile) drainage systems to reduce the duration of excess soil-water occurrences in the root-zone that damage crop growth and yield. The subsurface drainage practice provides other beneficial benefits as well, including improved filtration, reduced surface runoff and thus less soil erosion, and improved crop growth and yield when compared to the same or similar soil without a subsurface drainage system (Skaggs and van Schilfgaarde, 1999). It has been known for many years that subsurface drains reduce the losses of phosphorus and sediment from agricultural cropland, however, the loss of nitrate-Nitrogen was found to increase in sub-drainage outflows because of leaching from the soil profile by the subsurface drainage system (Gilliam et al., 1999). The nitrate leaching into subsurface drains has been studied, but during the last two decades concerns have been raised about the increasing size of hypoxic zone formed each year in the northern Gulf of Mexico (and elsewhere around the world). This concern has focused a renewed interest and need for additional subsurface drainage studies. The new studies provided a focus on drainage management because drainage of the soil profile was needed for optimum agricultural production, but a way needed to be found to avoid or greatly reduce the losses of fertilizer nutrients (especially nitrate-Nitrogen) with the drain outflows to surface receiving waters and streams. The original focus of the ADMS Task Force activities was the 8-State Midwest area including MN, IA, MO, IL, IN, OH, MI, and WI, because earlier EPA and USGS reports indicated that this region was the major source of the nitrate-Nitrogen lost from agricultural cropland that was carried down the Mississippi River System to the northern Gulf of Mexico and contributed to formation of the hypoxic zone.

The Concept of Nutrient Reduction by Drainage Water Management

There are two components involved to explain the nutrient reduction in the drainage outflow with drainage water management (controlled drainage); see example implementation in Fig. 1. First, the outflow drainage volume reduction by DWM results in a decreased discharge of nutrients (mostly nitrates) in almost direct proportion to the percent that the drain volume outflow is reduced (Gilliam et al., 1979; Evans et al 1989; Skaggs et al., 1994; Thomas et al., 1995). Second, by elevating the drainage outlet, any resulting decrease in the depth to the water table will cause the soil to become anaerobic and thus increase denitrification (Gilliam et a., 1979; Evans et al., 1989b; Kliewer and Gilliam, 1995; Thomas et al., 1995; Drury et al., 1997; Power et al., 2000). These effects of these two outcomes work together rather than separately, thus enhancing the reduction in nutrients discharged from the drain outlet.

Drainage water management research has shown reductions in nitrate outflow from subsurface drainage system by about 50% (Meek et al., 1970; Gilliam et al., 1979; Gilliam and Skaggs, 1986; Evans et al., 1989b; Skaggs and Chescheir, 1999; USDA-ARS, 2002; Fausey, 2004). In Sweden, Westrom et al. (2001) reported that during a dryer than normal or average year, nitrate loads in drainage outflow were reduced by 78% to 94% from drainage water management plots when compared to conventional drainage. Skaggs and Cheschier (1999) predicted with the DRAINMOD-N model that drainage water management reduced nitrate losses most effectively in closely spaced, deeper drains.

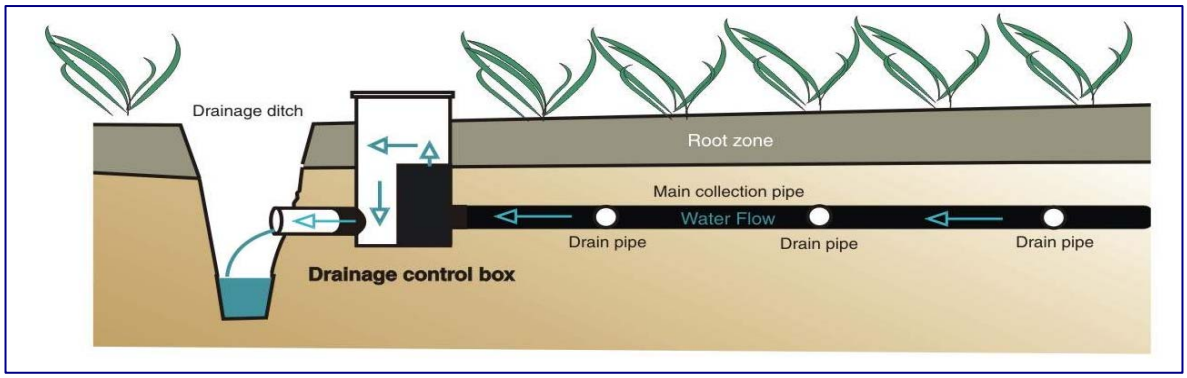

Fig. 1. Conceptual Drainage Outlet Control Structure in Subsurface Drain Main

As drainage water management (controlled-drainage) holds more water is in the soil profile, denitrification occurs, reducing nitrate concentrations in the saturated portion of the soil (Meek et al., 1970; Jacinthe, et al., 1999; Power et al., 2000). Jacinthe, et al. (1999) reported that during a 130 day study, 24% to 43% of the nitrogen present was denitrified when the water table was controlled at 10 cm below the soil surface.

The majority of nitrate load decrease observed from drainage water management is due to the volume of water and the nitrates in that water being held back within the soil profile (Gilliam et al., 1979, Evans et al., 1989b; Gilliam et al., 1999; Evans and Skaggs, 2004).

Drainage water management has the advantage that it does not require land to be removed from production because the soil profile is utilized for both water storage and creates the conditions for denitrification. A disadvantage is that drainage water management can only be used on relatively flat fields (i.e., 1% slope or less is preferred), but some recent technological flow-control developments may make it applicable to lands of greater slopes.

The ADMS Task Force and its Organizational Membership and Meetings

The Task Force was formally established in early 2003 as a technical work group (TWG) of USDA's Partnership Management Team (PMT) to assist in addressing and resolving water quality issues on agriculturally drained lands. The PMT was a collaborative effort among the USDA Agricultural Research Service (ARS); Natural Resources Conservation Service (NRCS); and the Cooperative State, Research, Education, and Extension Service (CSREES). Agricultural drainage management was one of 14 priority national research and technology development needs that were already identified by NRCS under the PMT Need-Request System, before it became a TWG.

Besides the principal Federal Government Agencies, ARS, NRCS, and CSREES that made up the PMT, other Federal Agencies that took an active part were the Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS). The main cooperative state agencies were the Minnesota Department of Agriculture and some Midwest State Departments of Environmental Quality (DEQ).

The Land Grant Universities in the Midwest had several members of their faculty, researchers, extension specialists, and instructors who initially took a very active role in the formation and activities of the Task Force, such as Iowa State University, University of Minnesota, University of Illinois, Purdue University, The Ohio State University, North Carolina State University, and Louisiana State University. By the second year of the ADMSTF, the University of Missouri, Michigan State University, and University of Wisconsin.

The Technical Committee and leadership of the ADMSTF was provided by a Chair – responsible for Technology, co-Chair – responsible for Implementation (these may be two co-Chairs), and an Executive Secretary – responsible for Education and Extension. In the first few years the Technology was handled by ARS, Implementation by NRCS, and Education and Extension by one of the Land Grant University professors in association with CSREES.

Although the ADM Coalition members were not official members of the ADMS Task Force (to avoid any legal conflicts of interest when voting on action items) they were invited to attend and participate in the discussions at Task Force meetings. Many of the ADMC members were representatives of drainage materials manufacturers and most were also members of the Corrugated Polyethylene Plastic Pipe Assoc. (CPPA) of the Plastic Pipe Institute, Inc. (PPI). At some of the Task Force meetings local drainage contractors were invited to attend and some made formal presentations or put on field demonstrations for the Task Force. Some drainage and water management consultants, who were members of the ADMC, often attended Task Force meetings to keep up to date with the technology. In addition, representatives from several non-Government Organizations have attended TF meetings, such as the National Corn Grower's Association; Sand County Foundation; IN Drainage District Association; IA Drainage District Association; Gulf of Mexico Program; Lower Mississippi River Basin Sub-Committee on Hypoxia; National Association of Conservation Districts (NACD); The Fertilizer Institute; The Nature Conservancy (TNC); and Ducks Unlimited. From 2002-2009, Task Force meetings have been held in IA (3), OH (4), IL (2), IN (2), FL, MN (3), LA, and NC, for a total of 17 meetings.

ADMS Research Findings

On behalf of the Task Force, Dr. Wayne Skaggs (c/o NCSU) completed a summary of past research findings. This summary report emphasizes that "Drainage Water Management" includes conventional drainage, controlled drainage, and subirrigation. While the emphasis has been on subsurface drainage, drainage water management includes surface drainage as well. Over the years the terms "water table management", "water table control", "reversible drainage", and "controlled and reversible drainage" have been coined to describe drainage systems that have facilities for some level of management, as opposed to passive, conventional drainage systems. Recently the term "drainage water management" has been proposed as a descriptive and politically acceptable term that can be used to describe any and all combinations of the above practices.

The report supports the conclusion -- based largely on the research in Ohio, Illinois, North Carolina, Michigan, and Louisiana -- that drainage water management can effectively reduce water flow and nitrate-Nitrogen loading during the non-growing season by an annual average of 30 to 60 percent. Producers can also receive an economical benefit from reduced losses of

inputs. Moreover, by using additional drainage management during the growing season, producers can mitigate dry spells or drought by capturing more water within the soil profile, mitigating yield reductions by 10-15 bushels of corn per acre. For example, research results from a 4.5-year field study, comparing controlled drainage to other drainage treatments in Northwest Ohio, showed that controlled drainage treatment reduced drainage outflows to about 60 percent of conventional drainage flows and nitrate-nitrogen loadings by more than 45 percent compared to conventional drainage; see Fig. 2.

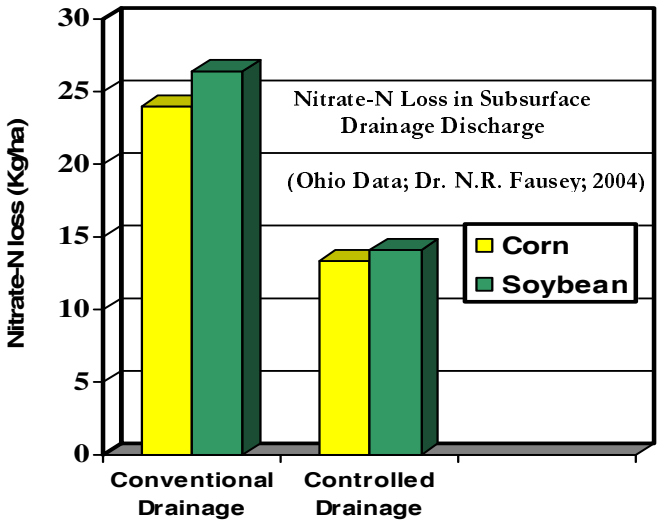

Fig. 2. Research Findings from Northwest Ohio

Field Implementation of Agricultural Drainage Management

Based on research findings documenting the water quality benefits of drainage water management, NRCS has provided funding for demonstrating the practice and further documenting benefits through the NRCS Conservation Innovation Grants Program (CIG) over the past several years. Six National CIG projects with almost $3 million in federal funds have been approved since 2004.

Technical and financial assistance has been made available to producers for implementing drainage water management through the Environmental Quality Incentives Program (EQIP) and the Conservation Security Program (CSP). Since 2004, approximately 56,000 acres have been planned and 23,000 acres implemented for drainage water management nationwide. Drainage water management practices have been planned on approximately 14,600 acres and applied on 6,700 acres within the 8-state focus area of the Task Force.

Challenges exist, however, in achieving widespread acceptance and adoption on the cropland potentially suitable for drainage water management. Producers have shown interest in drainage water management but mainly for the potential to increase yields that is not well documented. Technical capacity is limited for developing sound drainage water management plans – to help address this, Illinois NRCS offered an EQIP Ground and Surface Water Conservation Project in 2007 targeting development of drainage water management plans.

Recent ADMS Accomplishments

The Task Force worked with NRCS to develop a Fact Sheet for products and revised the Practice Standard 554, "Drainage Water Management," which highlights, in particular, the use of "control structures" that are placed in the main lines of subsurface drainage systems. The Fact Sheet points out that users need to consider drainage water management as part of conservation management system (CMS). Conservation practices such as drainage water management are normally implemented as part of a CMS that includes other practices such as nutrient management, riparian buffers, cover crops, filter strips, wetlands, etc. as needed to address identified natural resource concerns. Standards for the practices are available in the NRCS electronic Field Office Technical Guide (eFOTG; 2004): http://www.nrcs.usda.gov/Technical/Standards/nhcp.html

The Task Force has also developed a website on The Ohio State University computer system that contains the Charter, Action Plan, Goals and Objectives, Fact Sheet, and Flyer: http://www.ag.ohio-state.edu/~usdasdru/ADMS/ADMSindex.htm Other information such as an education and extension bulletins, recent summary of research findings, and linkages to other drainage water management conferences, activities, and meetings will be added to the website.

The Task Force organized its first technical session in 2004 entitled "*Drainage Water Management for the Midwest"* with a series of papers presented at the American Society of Agricultural Engineers (ASAE) **8th International Drainage Symposium**. The Task Force continues to plan, organize and participate in other conferences and symposiums that provide detailed engineering and scientific information on drainage water management practices and systems along with the latest status on Task Force projects and activities.

A recent research modeling/simulation accomplishment by Task Force members involved a preliminary evaluation of the potential water quality impact of applying drainage water management in an 8-state region of the Midwestern U.S. (Jaynes and Thorp, 2008; Thorp, et al. 2008). Their simulations were made with the hybrid model RZWQM-DSSAT,[3] to predict both conventional subsurface drainage and drainage water management performance in terms of hydrologic and nitrogen cycles over a 25-year period of historical weather at 48 locations across the 8-state region (MO, IA, MN, MI, WI, IL, IN, OH). They showed the DWM was suitable for about 7.2 million ha of cropland in the corn belt region. Their simulated average reduction in drain flow with DWM for the region was 151 mm/yr, and the regional reduction over the long term was predicted at 53%. This predicted reduction in nitrogen load down the Mississippi River System to the Gulf of Mexico was about 7% of the proposed 45% reduction by the year 2015 as recommended by the EPA National Research Council (NRC).[4] They estimated costs and indicated that the DWM practice was cost effective for reducing N-load at $1.53/kg-N/yr, and this was less than for other practices or methods compared (Jaynes and Thorp, 2008). The predicted regional reduction in nitrate-nitrogen losses through the drains was 18.9 kg-N/ha/yr, and the regional percent reduction over the long term was 51% (Thorp et al., 2008).

[3] The RZWQM-DDSAT hybrid model combines the Root Zone Water Quality Model with components of the Decision Support Systems for Agrotechnology Transfer model (Ma et al., 2005; Ma et al., 2006).
[4] Recent EPA reports indicate the year 2015 may no longer be realistic to reach the 45% reduction target goal.

Joint ADMC and ADMSTF Projects and Future Activities

NRCS developed a Drainage Water Management (DWM) Practice Standard 544 and conservation practice standards for the Midwestern States to provide cost-sharing assistance through NRCS to farmer's who implement DWM on their farms. When farmers began to ask more questions about how well DWM would work on their farms and in their soils, the ADMC and partnering members of the ADMSTF in the 5 States of IA, MN, IL, IN, and OH applied for and was granted a $1 million NRCS Conservation Innovation (CIG) Grant to install and conduct DWM demonstration projects on paired field-size demonstration sites in each of the 5 States. This CIG project is now in its third year of the 3-year grant period, and data collected will demonstrate the effectiveness of the DWM Systems for reducing nitrate loss is drainage outflows, reducing drainage volumes, and effects on crop yields. Rainfall is measured (monitored) at all demonstration sites and water table depth monitored at each DWM site. All sites have a satellite link that allows downloading of site data to remote PC equipment. Field Days and Workshops on DWM are conducted at each of these demonstration sites for farmers, contractors, consultants, State and Federal government agencies, and the General Public. Future endeavors to be undertaken by the Task Force will include promoting complementary conservation practices that can be combined with DWM, such as winter cover crops to further reduce the potential of nitrate loss from the cropland sites following annual crop harvest, and improvements in fertilizer application methods or fertility management practices. Other projects have evaluated the reduction in nitrate in subsurface drainage discharge by biofilters, saturated buffers, recycling of drainage water, and diversion of the drainage waters through wetland resource areas to reduce nitrate-load.

The Task Force is concentrating first on transferring drainage management technologies in demonstration projects in areas with suitable tile drainage systems. As these areas are identified, the Task Force will work with local sponsors and producers to develop and implement economically feasible research and demonstration projects. These will include the use of other management practices in combination with multiple drainages management practices. To further refine the existing technology, data will be gathered from these areas by conducting research and monitoring at the sub-watershed scale. A part of the project design would be to create the monitoring strategy for each project to assess water quality, such as reducing nonpoint source pollution; agronomic affects, such as yield changes and other crop growth attributes; water conservation effects for varying management strategies; soil quality affects for varying management strategies; and economic attributes, such as economic return on investment from drainage water management practices and systems. The researchers will collaborate with the landowner and local drainage district personnel to ensure the best-designed project and that no off-site problems with water drainage would develop.

The Task Force also is working to increase technical assistance, education, and extension activities. For example, ARS technical specialists are being asked to identify the best locations in the states on which to focus drainage water management projects identify pollutants to address, identify opportunities for wildlife habitat enhancement, and provide information to landowners. The Task Force plans to work with NRCS to draft practice standards at the state level for the projects. The Task Force is also interested in opportunities to cooperate with education and extension programs to educate landowners, conservation groups, and local and

state farm groups on drainage water management options that could be deployed in certain areas across a particular state. This will be instrumental in building support for the effort as well as in identifying potential landowning participants.

References

Drury, C.F., C.S. Tann, J.D. Gaynor, T.O. Oloya, I. J. van Wesenbeeck, and D.J. McKenney. 1997. Optimizing corn production and reducing nitrate losses with water table control-subirrigation. Soil Sci.Soc. Am. J. 61: 889-895.

EFOTG. 2004. National Resource and Conservation Service Field Office Technical Guide. Document can be found at the NRCS website: http://efotg.nrcs.usda.gov/technical/efotg/.

Evans, R.O., J.R. Cummings, and J.W. Gilliam. 1989a. Controlled drainage: A best management practice in North Carolina. ASAE Paper 892695. ASAE. St Joseph, MI.

Evans, R.O., J.W. Gilliam, and R.W. Skaggs. 1989b. Effects of agriculture water table management on drainage water quality. Tech. Rep. 237. Water Res. Inst., University of North Carolina, Raleigh.

Evans, R.O., J.W. Gilliam, R.W. Skaggs. 1991. Controlled drainage management guidelines for improving water quality. Publication NO. AG-443. N.C. Coop. Extension Service.

Evans, R.O., R.W. Skaggs, and J.W. Gilliam. 1995. Controlled drainage versus conventional drainage effects on water quality. J. of Irrig. Drain. Eng. 121(4): 271-276.

Evans, R.O. and R.W. Skaggs. 2004. Development of controlled drainage as a BMP in North Carolina. In: Drainage VIII Proceedings of the Eighth International Symposium, 21-24 (Sacramento, California USA). Ed. R. Cooke. Publication Date March 21, 2004. ASAE Publication Number 701P0304. ASAE, St Joseph, MI. Pp 1-15.

Gilliam, J.W., J.L. Baker, and K.R. Reddy. 1999. Chapter 24: Water Quality Effects of Drainage in Humid Regions. In: R.W. Skaggs and J. van Schilfgaarde eds. Agricultural Drainage. Agron. Monogr. 38. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA. Pp. 801-830.

Gilliam, J.W. and R.W. Skaggs. 1986 Controlled agricultural drainage to maintain water quality. J. Irrig Drain. Eng. 112: 254-263.

Gilliam, J.W., R.W. Skaggs, S.B. Weed. 1979. Drainage control to diminish nitrate loss from agricultural fields. J. Environ. Qual. 8(1): 137-142.

Jacinthe, P.A., W.A. Dick, and L.C. Brown. 1999. Bioremediation of nitrate-contaminated shallow soils using water table management techniques: Nitrate removal efficiency. Transactions of the ASAE. 42(5): 1251-1259.

Jaynes, D.B. and K.R. Thorp. 2008. Potential water quality impact of drainage watere management in the Midwest Cornbelt. ASABE Paper 084767. ASABE. St Joseph, MI.

Ma, L., G. Hoogenboom, L. R. Ahuja, D. C. Nielsen, and J. C. Ascough II. 2005. Development and evaluation of the RZWQM-CROPGRO hybrid model for soybean production. *Agronomy J.* 97(4): 1172-1182.

Ma, L., G. Hoogenboom, L. R. Ahuja, J. C. Ascough II, and S. A. Saseendran. 2006. Evaluation of the RZWQM-CERES-Maize hybrid model for maize production. *Agric. Systems* 87(3): 274-295.

Meek, B.B., L.B. Grass, L.S. Willardson, and A.J. MacKenzie. 1970. Nitrate transformation in a column with controlled water table. Soil Sci. Soc. Am. Proc. 34(2): 235-239.

NRCS Performance Results System 2004 – 2008 data.

NRCS Conservation Innovation Grant Program information. (http://www.nrcs.usda.gov/programs/cig/)

Pitts, Donald J. 2008. Drainage Water Management: The Illinois Experience, Prepared for presentation at University of Minnesota, Southwest Research and Outreach Center at Lamberton, MN on August 13-14, 2008.

Power, J.F., R. Wiese, and D. Flowerday. 2000. Managing nitrogen for water quality –Lessons from management systems evaluation area. J. Environ. Qual. 29: 355-366.

Skaggs, R.W., M.A. Breve, and J.W. Gilliam. 1994. Hydrology and water quality impacts of agricultural drainage. Critical Reviews in Environmental Science and Technology. 24: 1-32.

Skaggs, R.W. and G.M. Chescheir. 1999. Chapter 15: Application of drainage simulation models. In: R.W. Skaggs and J. van Schilfgaarde eds. Agricultural Drainage. Agron. Monogr. 38. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc., Madison, Wisconsin, USA. Pp. 537-564.

Skaggs, R.W. and J. van Schilfgaarde (Eds.). 1999. Agricultural Drainage, Agronomy Monograph 38, 1328 pp. American Society of Agronomy, Madison, Wisconsin.

Thomas, D.L., C.D. Perry, R.O. Evans, F.T. Izuno, K.C. Stone, and J.W. Gilliam. 1995. Agricultural drainage effects on water quality in Southeastern U.S. J. of Irrig. Drain. Eng. 121(4): 277-282.

Thorp, K.R., R.W. Malone, and D.B. Jaynes. 2007. Simulating long-term effects of nitrogen application rates on corn yield and nitrogen dynamics. Transactions of the ASABE 50(4): 1287-1303.

Thorp, K.R., D.B. Jaynes, and R.W. Malone. 2008. Simulating the long-term performance of drainage water management across the Midwestern United States. Transactions of the ASABE. 51(3): 961-976.

USDA, ARS. 2002. Draining the land without polluting the waters. Agricultural Research. Vol. 50, No. 10, October 2002. p. 4-8.

Wesstrom, I., I. Messing, H. Linner, and J. Lindstrom. 2001. Controlled drainage – effects on drain outflow and water quality. Agricultural Water Management. 47:85-100.