Planning a Drainage Water Management System

Jane R. Frankenberger, Purdue University and Gary R. Sands, University of Minnesota

WHAT IS DRAINAGE WATER MANAGEMENT?

Drainage water management (DWM) is the practice of raising the drainage outlet during times of the year when drainage is not needed or a higher water table could benefit the crop. DWM allows producers to have more control over drainage. They can raise the outlet after harvest to limit drainage outflow during the off-season when drainage is not needed, holding water and nutrients in the field to improve water quality. They can lower the outlet before field operations in the spring, so that the drain can flow freely and the field can dry down. After planting and spring field operations, they can raise the outlet again to create a potential to store water that could be used by the crop in midsummer and potentially increase crop yield.

Figure 1: Drainage water management systems allow producers to have more control over drainage.

WATER MANAGEMENT ZONES

Water management zones are areas of the field where the water table can be kept at roughly an equal depth with a water control structure. (Figure 2) A completely flat field could be managed with only one structure. However even the flattest fields generally have a slight slope, limiting the influence of a single control structure and thereby requiring multiple water management zones.

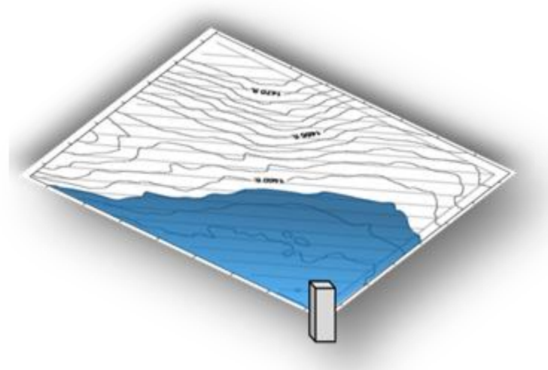

Figure 2: Illustration of a water management zone.

The elevation difference within one zone should be as small as possible. A reasonable goal might be 1 to 1.5 feet, although many systems have been designed with an elevation difference of 2 feet. A smaller elevation difference (i.e., 1 foot or less) is more effective at holding the water table constant throughout the zone, and therefore provides greater benefits for crop growth and water quality. However, placing a water control structure every 1 foot change in elevation would be more expensive because more structures are needed. Reducing the elevation difference within a zone (degree of control) and keeping the number of zones manageable is the objective of a good DWM design (Figure 3).

A rule of thumb for economical implementation of DWM is that one structure should be able to influence at least 15 to 20 acres. The more acres that can be influenced, the better. In sites in Minnesota and Illinois, a single structure was able to influence approximately 140 acres. Although few sites will have zones of that size, it suggests that searching for sites with topography that fits DWM is worthwhile.

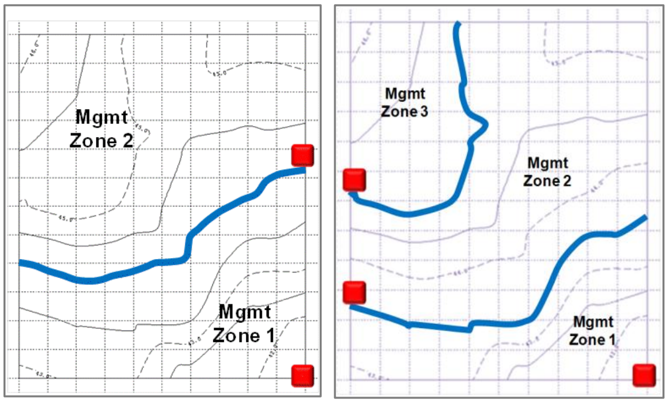

Figure 3: DWM planning involves determining water management zones that balance the need for a cost-effective system (fewer, larger zones, as shown at left) with the need for a uniform water table (less elevation difference, as shown at right).

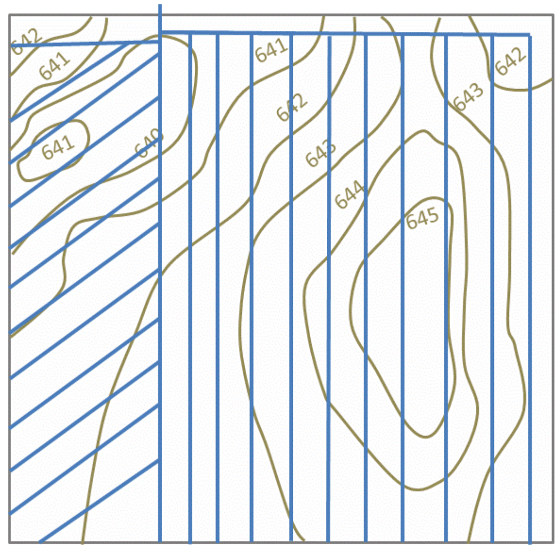

Figure 4b: Existing drainage system (blue lines)

APPLYING DRAINAGE WATER MANAGEMENT TO EXISTING DRAINAGE SYSTEMS

The feasibility of DWM in a field with an existing drainage system depends on (1) the field's topography, (2) the existing drainage system layout, and (3) how the two fit together. Consider the field for which a (4a) topographic and (4b) tile map are shown in Figure 4. The total elevation difference in this field is about 5 feet, and the average slope, assuming a 40-acre field, is about 0.6%. Is this field a good candidate for DWM?

Figure 4a: Topography (1 foot contours)

The average slope of the field exceeds the ideal of less than about 0.5%, but slopes less than 1% are often considered feasible. Therefore it is useful to develop and analyze potential designs. First, consider what happens if a control structure is put at the single outlet, at approximately 640 feet elevation (Figure 4). The area considered to be controlled (to a 2-ft elevation difference, in this case) is shown in blue, extending to the 642-ft contour line. In this case, the impacted area is controlled only by the elevation.

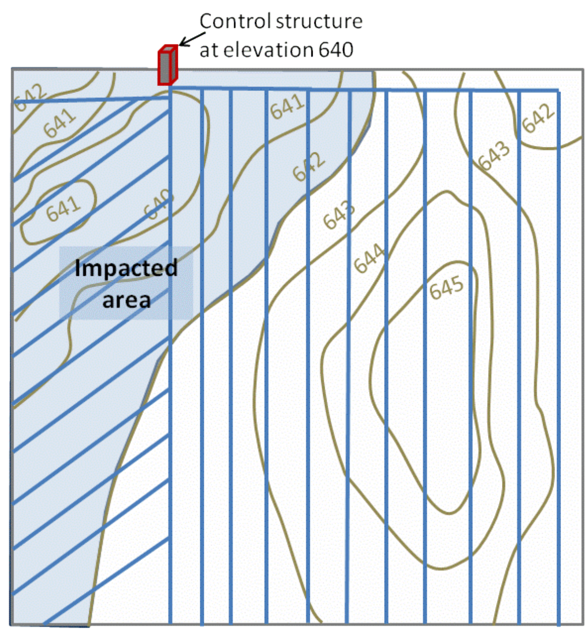

Figure 5: Area impacted by a single water control structure at the existing outlet

What if another outlet is added to the field so that an additional control structure can be placed at 642 feet elevation (Figure 6)? The area impacted by the new control structure is limited by two characteristics:

(1) field topography: The hill in this part of the field goes above 645 feet, but the structure at 642 feet can only impact the part up to 644 feet, and also
(2) location of the drain lines. The laterals that could be impacted by the control structure at 642 feet outlet into the main that has the control at 640 feet. Therefore, that section of the field is not controlled.

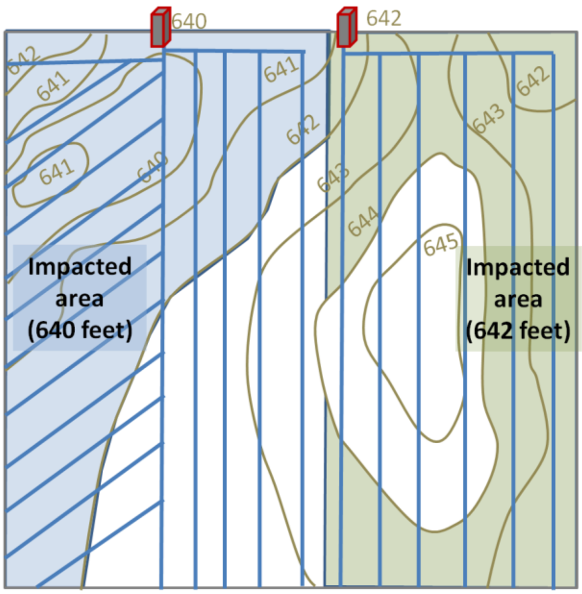

Figure 6: Area impacted by two water control structures

This example shows the limitations of retrofitting DWM in fields that are already drained, and the importance of designing tile systems with DWM in mind, as described in the next section.

DESIGNING NEW DRAINAGE SYSTEMS WITH DRAINAGE MANAGEMENT IN MIND

The original drainage system in the previous example could have been designed to allow a greater proportion of the field to be impacted by DWM. Figure 7 shows an alternative design, directing drainage from the area above the 642 foot contour towards the second outlet. Such a design would make the practice cost less on a per-acre basis. Other configurations of mains and laterals are also possible, including a single sub-main, to provide one outlet at the 640-ft control structure.

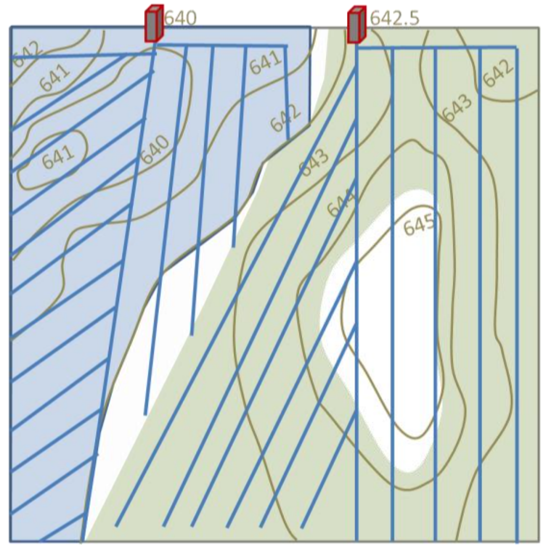

Figure 7: Alternative drainage design that would allow more area to be impacted by two control structures

Designing with DWM in mind generally means installing laterals **to be aligned** with the field contours as much as possible (Figure 7a) rather than **perpendicular to** the contours (Figure 7b).

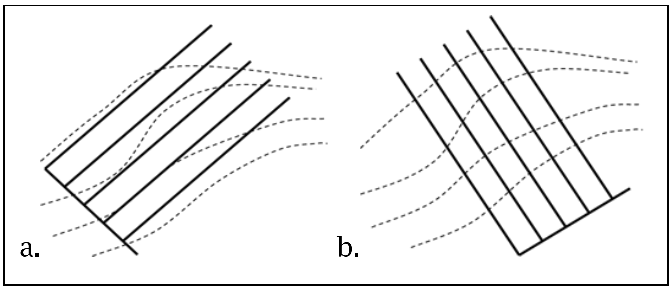

Figure 8 (a): Laterals following the contours lead to economical DWM systems; (b): Laterals perpendicular to the contours limit DWM.

New global positioning systems (GPS)-guided drainage mapping and installation equipment makes installing drainage lines with the field contours more practical than it was in the past. Entire systems can be designed to follow the contour as illustrated in Figure 9. A new drainage system designed with DWM in mind (where appropriate) will make retrofitting the practice feasible in the future, whereas without the DWM approach, the field may end up being more like our first example, with a poor DWM fit.

Figure 9: Drainage installation following the contours will make DWM more cost-effective.

STEPS IN PLANNING A DRAINAGE WATER MANAGEMENT SYSTEM ON A DRAINED FIELD

Developing a plan requires (1) acquiring maps, (2) clarifying goals of the system, (3) designing the system, and (4) developing a management plan showing dates and depths for the outlet. These steps are discussed below.

1. Acquire topographic, tile, and soil maps

Topographic maps

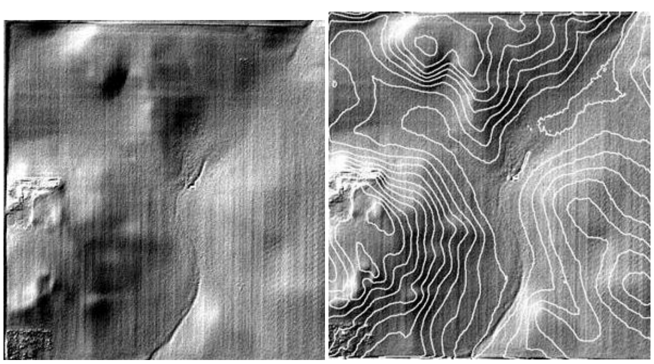

Figure 10: LiDAR data provides elevation data that can be used for DWM system planning. (Left: LiDAR data; Right: Contours developed from the LiDAR.)

A good elevation (topographic) map is critical for planning a DWM system. Elevation data is usually collected by surveying the field, either with traditional laser systems or real-time kinematic (RTK) GPS that has the capability of collecting horizontal and vertical position sub-inch accuracy. LiDAR (Light Detection and Ranging) is becoming more widely available, and is the first remotely-sensed data accurate enough to use in planning drainage systems. Although LiDAR may not be adequate for use in final design or installation, it can provide data for use in planning DWM zones and determining feasibility. (Figure 10)

Current and complete tile map

Retrofitting an existing drainage system for DWM requires a tile map that is current and accurate. This requirement does eliminate some fields from consideration, since many older tile systems were not mapped when they were installed. In some cases, aerial photos can be used to locate tiles.

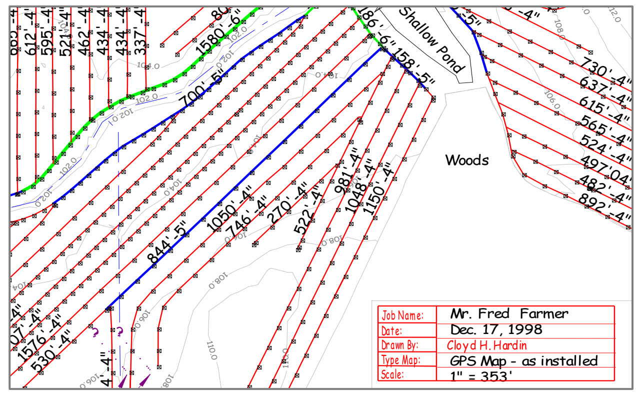

Figure 11: Example of existing tile map with contours.

Soil maps and information

A soil map is usually included in a DWM plan. Soil information is available from the USDA Natural Resources Conservation Service nationwide. Paper books are generally no longer available, and soil information is instead accessed through digital tools. The UDA's Web Soil Survey provides an easy way to access the soil map for a particular field, and obtain a map and report. (Figure 12; See the "For More Information" section at the end of this publication for information on accessing this and other tools discussed.)

An alternative tool is "SoilWeb", a web-based or mobile app developed by UC-Davis Soil Resource Lab, designed to display USDA-NRCS soil survey data. This resource provides online maps, mobile maps based on location, or soil lines and information in Googleearth. The Googleearth method allows you to view the soil lines in 3 dimensions, which can be very helpful for understanding the different landscape positions of the soils (Figure 13).

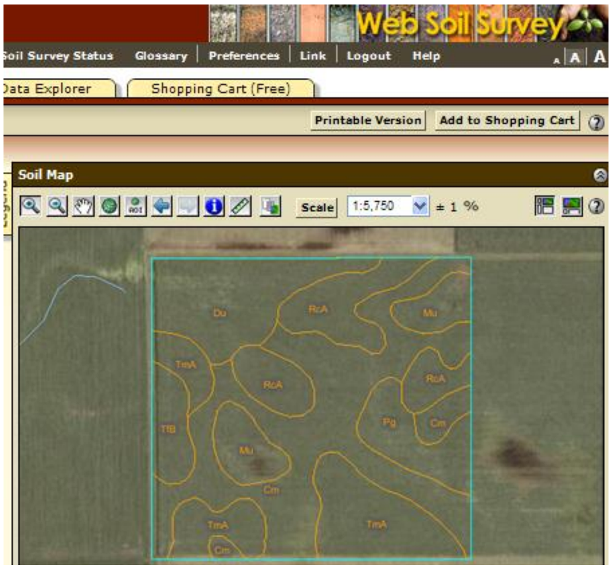

Figure 12: The USDA Web Soil Survey provides online soil maps and reports on soil properties.

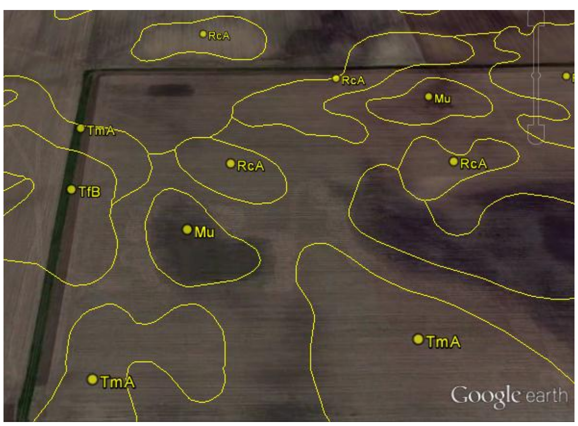

Figure 13: SoilWeb, developed by the California Soil Resources Lab, shows soil and its properties in Google earth.

2. Clarify the system goals

Drainage water management can be implemented for various purposes, and the goals of a specific system should be clarified by the landowner or producer. The USDA Natural Resources Conservation Service Conservation Practice Standard 554 lists five possible purposes:

a) Reduce nutrient, pathogen, and/or pesticide loading from drainage systems into downstream receiving waters
b) Improve productivity, health, and vigor of plants
c) Reduce oxidation of organic matter in soils
d) Reduce wind erosion or particulate matter (dust) emissions
e) Provide seasonal wildlife habitat.

The goals of most DWM systems in the Midwest are (a) reducing nutrient loading and (b) increasing crop yields. But DWM can also be used to meet other goals, including protecting organic soils from oxidizing, reducing wind erosion, providing greater hydrologic control for drainage, and providing habitat for waterfowl by raising the water table to the surface or even above the surface in the late fall. Although not listed among these five major goals, DWM can also be used during and after manure application, to prevent preferential flow of liquid manure directly to the ditch or stream.

3. Design the retrofit system

Developing a final design that can be used for installation requires experience and training, and is beyond the scope of this publication. In creating a design or discussing a design with a contractor or drainage designer, it is useful to remember that the challenge of designing a cost-effective system for a field with an existing drainage system is to find a way to impact at least 15 to 20 acres per water control structure. Unfortunately, DWM may not be feasible on all fields.

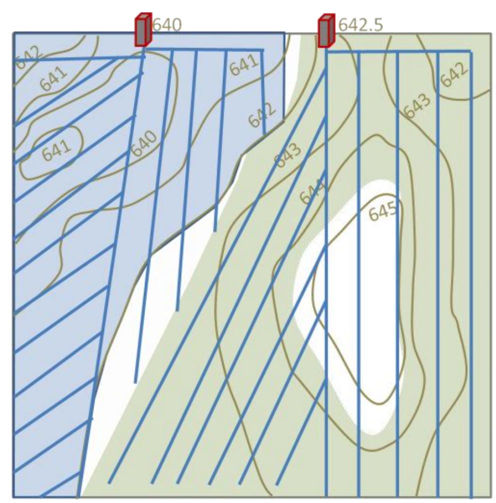

Figure 14: A DWM design shows the topography, drainage system, and impacted area

4. Develop a management plan with dates and outlet depths

The best management strategy depends on the producer's goals, as discussed above.

A management strategy that retains water during the off-season and raises the water table after planting can achieve the goals of reduced nutrient loads downstream, and also increased yields in many, but not all years. Figure 15 shows a basic strategy for meeting these goals. (A) The outlet is lowered to the depth of the drain, to dry the field for planting; (B) The outlet is raised to a depth of 2 feet from the surface after planting to retain water that may benefit crop yields; (C) The outlet is lowered for harvest and fall field work, and (D) raised to within 6 inches of the surface for the off-season (winter) when drainage is not needed. The outlet should be raised as soon as possible after fall field work (D), and kept in an elevated position as long as possible before spring field work (A) to achieve maximum water quality benefits. The specific management depths should be determined by the producer to make sure they meet crop system goals. It is important to note that the desired water table depth may not be achieved if rainfall is insufficient to produce a water table.

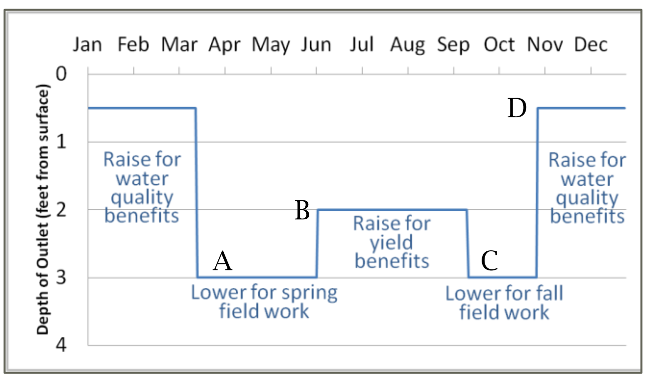

Figure 15: A basic management strategy to meet the goals of reducing nutrient loads and improving crop yield

Management of the system can also be more complex. For example, to gain more water storage after planting, the outlet can be raised within 1 foot of the surface before crop roots start to grow deep into the soil. In employing this strategy, the outlet must be lowered again before the roots are 6 inches long. Although it involves more work, such a strategy provides an opportunity to retain more water (Figure 16a). If providing seasonal habitat for waterfowl is a goal, the water table during the winter should be at the soil surface or higher Figure 16b also shows that management during the growing season may not be the goal of all producers.

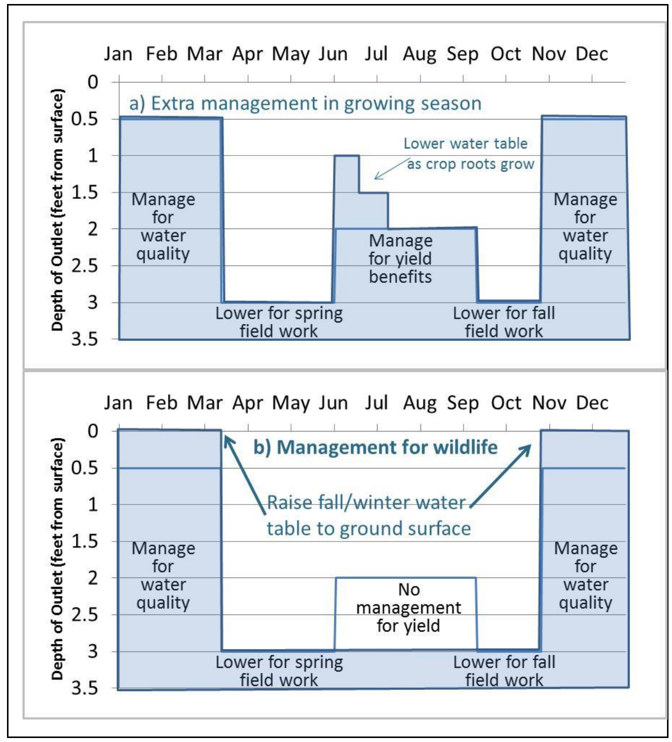

Figure 16: Example alternative management strategies. (a) To maximize water storage, the outlet can be raised high after planting and lowered as crops grow. (b) Raising the outlet to the surface can provide seasonal habitat for wildlife. Management in growing season is optional, and may not be desired by all producers.

DRAINAGE WATER MANAGEMENT PLANS

The USDA Natural Resources Conservation Service provides funding for a Conservation Activity Plan (CAP 130) that provides the information described in steps (1) to (4). Such a plan must be developed by a certified Technical Service Provider (TSP). Obtaining such a plan allows producers to explore whether DWM can fit into their cropping system plan. A CAP 130 plan includes the following elements:

- Farm/field information
- Producer objectives
- Maps of fields/soils/drainage systems/wetland delineations
- Drainage water management zones
- Conservation practices & infrastructure needed

- Drainage water management schedule
- Management instructions

An additional requirement for DWM plans and implementation funded by the USDA Natural Resources Conservation Service is ensuring that the system does not cause adverse impacts to other properties or drainage systems.

FINAL THOUGHTS

Drainage water management offers an opportunity to limit nutrient losses and potentially improve crop yields on drained cropland, compared to conventional (free) drainage systems. Planning a DWM system requires detailed maps, experience, and training to ensure a good design. Designing a new drainage system with DWM in mind will ensure the greatest efficacy if the practice is eventually implemented for the field. For fields that already have subsurface drainage systems, DWM is usually economically feasible only when the layout allows for the management of at least 15 to 20 acres for each water control structure. Proper management of the system by the producer helps to ensure that the system will be as effective as possible. Although not all fields meet the requirements for the practice, for those that do, DWM can be a strategic investment in water and nutrient management for the 21st century.

FOR MORE INFORMATION

- Web Soil Survey: http://websoilsurvey.nrcs.usda.gov/
- SoilWeb: http://casoilresource.lawr.ucdavis.edu; Click "Online Soil Survey"
- *Questions and Answers About Drainage Water Management for the Midwest* (Regional publication with 10 authors; online at http://www.extension.purdue.edu/extmedia/WQ/WQ-44.pdf
- University of Minnesota Drainage Outlet: http://wwwDrainageOutlet.umn.edu
- Conservation Drainage for the Midwest web site: http://engineering.purdue.edu/watersheds/conservationdrainage
- NRCS Conservation Practice Standard 554, "Drainage Water Management," and 587, "Structure for Water Control." State and local standards are in Section IV of the Electronic Field Office Technical Guide (eFOTG) at http://www.nrcs.usda.gov/technical/efotg/
- "Operating Controlled Drainage and Subirrigation Systems" by R. Evans and R.W. Skaggs. North Carolina Cooperative Extension Service, Publication Number AG 356, 1996. http://www.bae.ncsu.edu/programs/extension/evans/ag356.html
- USDA NRCS National Engineering Handbook Part 624, Chapter 10, "Water Table Control," ftp://ftp.wcc.nrcs.usda.gov/water_mgt/EFH&NEH_Drainage_Chapters/neh624_10.pdf
- *Subsurface Drainage Design and Management to Meet Agronomic and Environmental Goals.* 2011. J.S. Strock, G.R. Sands, and M.J. Helmers. In: Soil Management: Building a Stable Base for Agriculture. J.L. Hatfield and T.J. Sauer (eds.). American Society of Agronomy and Soil Science Society of America, 5585 Guilford Road, Madison, WI 53711, US

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