Drainage Water Management for Midwestern Row Crop Agriculture

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GLOSSARY

Artificial subsurface drains or subsurface drains---drains made of clay, cement, or plastic with open joints or slots to collect and carry excess water from the soil.

Conventional or free drainage---artificial subsurface drains without restrictions, controls or pumps.

Control plan---drainage water management plan to set water table levels to restrict outflows over a period of time.

Control structures---a structure installed in a tile line to raise and lower the water table in a field.

Drainage coefficient---the depth of water, in inches, to be removed from an area in 24 hours.

Drainage intensity---the use of closer spaced, smaller drainage lines to even out the water table without changing the drainage coefficient.

Drainage system---collection of surface ditches or subsurface drains, together with structures and pumps used to collect and dispose of excess surface or subsurface water.

DWM (Drainage Water Management)---a practice of using water control structure in a main, sub main, or lateral drain to vary the depth of the water table.

Fallow season--- the part of the year that there is no growing crop in the field.

Managed drainage---drainage systems that are equipped with control systems that can be sued to regulate the rate of flow of water from a field.

Paired watershed design---an experimental design that compares two (or more) similar watersheds under different management systems.

Seasonal high water table---seasonal high water table is a zone of saturation at the highest average depth during the wettest season. It is at least 6 inches thick, persists in the soil for more than a few weeks, and is within 6 feet of the soil surface. Soils that have a seasonal high water table are classified according to the depth to water table, kind of water table, and time of year when water table is highest.

Shallow drainage---drainage tile installed at a depth one foot less than the normal installation depth indicated for a particular soil type.

Stop log---a singular or multiple block installed in a control structure to raise or lower the water table in a drainage system.

Tile lateral---secondary tile lines that extend into a field to collect water and carry it to the main line.

Tile main---a principle tile line that collects water from a series of smaller tile lines or laterals and connects them to the outlet (ditch, stream, etc.).

Tillage systems:

a) **Conventional till---**plowing, disking, or cultivating the soil to reduce the residue for crop production.

b) **Conservation till---**minimum tillage, ridge tillage, strip tillage that reduces crop residue by 30% or more but less than 70%.

c) **No till---**Tillage that disturbs no more than 30% of the surface residue.

Water deficient stress--- stress induced in plants due to lowered water potential.

Water table---water table is the level at which the groundwater pressure is equal to atmospheric pressure. As water infiltrates through pore spaces in the soil, it first passes through the zone of aeration, where the soil is unsaturated. At increasing depths water fills in more spaces, until the zone of saturation is reached. The relatively horizontal plane atop this zone constitutes the water table

Watershed---total land area above a given point on a stream or waterway that contributes runoff to that point.

INTRODUCTION

Artificial subsurface drainage systems have been in use in the Midwest for over 150 years. These systems facilitate crop production in areas that would be otherwise unsuitable, and increase production in others. They were designed for the sole purpose of quickly removing excess water from the plant root zone to prevent stress and to improve crop yields and soil conditions, but with no consideration of their effects on water quality. Subsurface or “tile” drainage is a common practice in agricultural regions with seasonally high water tables. The practice of subsurface drainage provides many agronomic and environmental benefits, including greater water infiltration, lower surface runoff and erosion, and improved crop growth and yield compared with similar agricultural soils without subsurface drainage. However, subsurface drains have been found to increase losses of nitrate-N, which is of increasing concern because of the significant contribution to nitrate in the Mississippi River from drained agricultural land in the Midwest.

This project demonstrated the unique technology of drainage water management (DWM), the practice of managing water table depths to reduce nutrient transport from subsurface drains during the fallow season and to reduce water deficit stress during the growing season. Considering that no such guidance currently exists, this innovative multi-state Conservation Innovation Grant (CIG) project was designed to develop a set of regional recommendations to facilitate and encourage the widespread adoption of DWM. Farmers played a central role in assessing the economic effects of DWM on farm profitability. Each demonstration field used the latest technologies, including satellite-controlled water control structures, resulting in a truly managed water table by farming landowners. Implementation of the project documented nutrient outflows from DWM, a necessary step in future programs for nutrient trading. Finally, and in addition to traditional tools, we used outreach methods that utilize farmer-to-farmer contact, such as farm forums.

Drainage water management is a practice that shows great promise for reducing nitrate loading in the Midwest while maintaining drainage intensity during critical periods of the crop production cycle. DWM uses water control structures to raise the effective height of the water table, and thereby manage the amount of drainage from a field. While past research has shown the effectiveness of DWM at the plot scale, we believe that implementation on a larger field scale level sheds new light on the benefits to Midwestern farmers. We used cutting edge technology that will pioneer more rapid adoption of this practice, since drainage water management requires considerable attention by the producer. Our sites were outfitted with satellite-controlled structures that allowed the producers to monitor flow, water table level and rainfall from a home computer connected to the internet.

This project also demonstrated and evaluated the water quality, soil quality, and economic impacts of the practice on private farms in five states: Minnesota, Iowa, Illinois, Indiana, and Ohio. By comparing results among sites and conditions on a regional basis, we can produce guidance that can be used in a comprehensive fashion that can only be achieved by looking a variety of field conditions to better understand the variances within the entire region. We also investigated the economic impact of DWM on the profitability of the farm. For example, the impact on yield was assumed to be positive (based on the potential to hold water that can be used later in the season), but hard data was needed to draw conclusions. ADMC devoted considerable attention to "getting the word out" on drainage water management directly to farmers and others by conducting farm forums, preparing media articles, promoting the practice to resource agency and extension field offices, and conducting seminars in other localities where the practice has merit.

PROJECT ACTIVITIES

There were five main focus areas:

- Engage producers in demonstration of the multiple benefits of DWM on farm economics, soil quality, and water quality;
- Test the magnitude of the nutrient reduction benefits that can be achieved with DWM;
- Improve the water and nutrient accounting for these systems;
- Assess earthworm activity and soil organic matter changes; and
- Disseminate this information to the farming community.

Field Evaluations (Objectives 1 and 2)

In each of the five states, we monitored new and/or existing field sites to evaluate the environmental effectiveness of DWM. The sites were all selected so that DWM could be compared to conventional drainage on fields or parts of fields with similar soils, drainage systems, management histories and yields. Each field site was planted with the same corn hybrid or soybean variety and treated with the same pesticides and fertilizer application rates, allowing us to use the paired watershed design to determine the impacts of DWM with a statistically supported methodology. Monitoring was conducted for nitrate concentration and water flow from tile drains in fields with DWM vs. those with conventional free drainage. In addition, several sites were monitored for water table depths to evaluate water losses via other pathways and to improve water and nutrient accounting. On each site, we monitored crop yields and profitability – critical factors for producer adoption. Further, a portion of sites were monitored for earthworms and soil quality.

***Flow, water quality, and water table* -** Water flow rates from subsurface drainage were monitored, and water samples for nitrate analysis were taken approximately weekly at all sites, and more frequently during high flow periods. Water flow and nitrate concentration measurements were used to calculate the reduction in nitrate loads resulting from DWM practices. These measurements evaluated and improved the nutrient accounting for DWM by determining whether there were significant losses of water and nitrate via deep or lateral seepage.
***Soil quality* -** Sites were monitored for potential changes in soil quality as a result of DWM by measuring soil properties at the beginning and end of the project. In Indiana, sites were initially assessed in 2007 for earthworm populations, aggregate stability, bulk density, and penetration resistance and were measured again at the end of the project. In Iowa, properties that were measured included those typically used in the Soil Management Assessment Framework. Changes in the soil quality indicators were used to determine if the NRCS Soil Conditioning Index needs to be modified before it can be applied to DWM in the Midwest. In addition, Indiana provided assessments of earthworm populations at several sites

Farm field profitability and time requirements **-** The economic benefits of DWM were estimated by monitoring crop yields and production costs at each site. Yield monitors and GPS systems were used in the measurement of each year's grain harvest. Field scouts also monitored changes in weed or disease incidence. Participating growers were asked to record time devoted to drainage management, along with the date and other work related activities that same day. Information on other activities helped estimate an opportunity cost of the time devoted to drainage management.

Data summary and technology transfer (Objective 3)

A database of the different sites, with their soil, crop, drainage system, slope, climate, and other relevant factors was developed. Results from the different sites were analyzed to explain similarities and differences in effectiveness. One focus is to provide data to the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) that will assist in determining program priorities and payment dollars for DWM. Another is to help ADMC, NRCS and other drainage-oriented organizations to better train drainage contractors.

ADMC also held a series of 10 farm forums at individual producers' farms distributed throughout the region. The ADMC invited local farmers and media to demonstration farms in each participating state to discuss DWM strategies in an informal setting. This format, well tested in the Midwest, attracts an average of 30 to 40 local farmers to each event. We conducted these sessions in the machine sheds or on the farmsteads of participating farmers, inviting experts from the participating land grant university, the drainage industry and the farm media to participate in these neighbor-to-neighbor discussions of DWM strategies.

ADMC also developed a comprehensive instructional publication that will be used in conjunction with NCRS efforts, as well as the variety of seminars that will be conducted as a part of this project. However, the publication is comprehensive enough to use as a stand-alone product that will help a producer make DWM decisions, evaluate his or her water management efforts, and formulate a solid plan for drainage improvement on their farm ADMC involved NRCS staff in developing copy, evaluating the message and in selecting contractors to develop and distribute the publication ADMC also developed other printed materials that were published as articles in major Midwest farm publications, including, but not limited to the *Farm Journal, The Farmer, Progressive Farmer, Farm Industry News, LICA Contractor, Drainage Contractor, Land and Water,* and *Successful Farming.* These articles included the perspective of farmers, drainage contractors, agency personnel and researchers to better convey a variety of DWM themes. Finally, ADMC produced a website where data is gathered and disseminated in a central location. The material further supports the efforts to promote the understanding of drainage and nutrient enrichment issues, and the adoption of drainage water management practices.

COLLABORATORS

The Agricultural Drainage Management Coalition (ADMC) is a nationwide group of agricultural, industry, and environmental interests that have come together to promote DWM and other conservation drainage practices. ADMC is comprised of over 60 key stakeholders and supporters, including drainage contractors, individual farmers, agricultural groups such as the National Corn Growers Association, The Fertilizer Institute, drainage industry manufacturers and suppliers, and environmental groups. The Agricultural Drainage Management Systems Task Force (ADMSTF) is a multi-agency and university collaboration that has met regularly since 2002 to develop a national effort for implementing improved DWM practices and systems that will enhance crop production, conserve water, and reduce adverse off–site impacts on water quality and quantity. The Task Force members from five key Midwestern drainage states collaborated with the ADMC on this proposed project.

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CIG EXECUTIVE SUMMARY

The field evaluation of drainage water management (DWM) for Midwestern row crop agriculture was completed by the Agricultural Drainage Management Coalition and its partners from the five states of Iowa, Minnesota, Illinois, Indiana and Ohio. The project entailed four paired field evaluations in each of the five states. The partners on this project included Purdue University, Iowa State University, Ohio State University, USDA-Agricultural Research Service, Minnesota Department of Agriculture, University of Minnesota and University of Illinois.

Drainage water management uses water control structures to raise the effective height of the water table, thereby managing the amount of drainage from a field. DWM is a practice that shows great promise for reducing nitrate loading in the Midwest while maintaining drainage intensity during critical periods of the crop production cycle.

This project demonstrated the impact of managing water table depths to reduce nutrient transport from subsurface drains during the fallow season and to reduce water deficit stress during the growing season. Changing the stop logs in the DWM control structure during the year is subject to the timing of the spring field operations and completion of fall field work. NRCS Practice 554 specifies a 30-day window for changes in the water table levels. All of the field evaluations were operated like the producers' normal farming operations with the exception of managing the control structures in the drainage systems.

The 20 field evaluations included data on nutrient reductions, crop yields, profitability, and timing of drainage water management, precipitation and drainage outflows from each field plot. The results from the different plots helped highlight the regional differences from state to state and, in some cases, fields within a state.

The state tables in this report list precipitation, drainage outflows, nutrient reductions and crop yields. Profitability of DWM is hard to quantify due to the inconsistency of yield information. However, a table of estimated installation costs and an equation to estimate annualized costs of implementation are included in this document.

The variable that could not be controlled in this project was precipitation – when it was received and the amount received. Precipitation was compared to the 30-year average at each location.

All of the field demonstration sites were retrofits with the exception of the Windom site in Minnesota which was designed specifically for drainage water management. Using retrofit drainage systems was somewhat challenging because the area of DWM impact was not always maximized and the tile installation maps were not always accurate. Some of the sites do not have any nutrient or yield data for 2007 year because their systems were being installed that year.

In reviewing the data from the individual state charts, it is apparent that reductions in nitrate outflow of 20 to 60% can be achieved, depending on the amount of precipitation received and when it occurs. There appears to be greater reductions in the southern part of the Corn Belt vs. the northern Corn Belt. This may be due to the frozen soils in the northern Corn Belt during the fallow season.

To implement this practice, a producer or landowner needs a good set of topographic maps in 6-inch contours to develop a plan for DWM. Many producers are already collecting this information through the use of GPS equipment on their tractors, combines or field sprayers. Sometimes this information can be supplied by a custom applicator of agricultural inputs or a drainage contractor with GPS-enabled equipment. With a good topo map, field map, existing tile maps and soils information, a technical service provider or drainage contractor trained in DWM design could produce a DWM system for the producer or landowner.

Equation to Estimate Annualized Cost of Installation

(Cost of Materials + Installation Costs + Mobilization) ÷ # of Acres = Annualized Costs

Amortization schedule (Interest Rate + Number of Years)

Example: ($715 + $55 + $58 + $450 + $150) ÷ 20 acres = $7.35/yr

(6% interest / 15 years)

Estimated Cost of DWM Installation

Size of Tile Main	**6"**	**8"**	**10"**	**12"**
Control Structure	$ 617.00	$ 715.00	$ 803.00	$ 1,002.00
Anti-seep Collar	$ 55.00	$ 55.00	$ 55.00	$ 55.00
20' of DW Non-perf	$ 36.00	$ 58.00	$ 78.00	$ 107.00
Installation Costs	$ 450.00	$ 450.00	$ 450.00	$ 450.00
Subtotal	**$ 1,158.00**	**$ 1,278.00**	**$ 1,386.00**	**$ 1,614.00**
Mobilization Costs	$ 150.00	$ 150.00	$ 150.00	$ 150.00
Total if Retrofit Only	**$ 1,308.00**	**$ 1,428.00**	**$ 1,536.00**	**$ 1,764.00**

CIG Results by State

Indiana CIG Results

MD-Managed Drainage CD-Conventional Drainage

	Precipitation/inches			In/outflows/Type of system		% Reduction	Nitrate Loss lbs/acre		% Reduction	Yields		
Site/yr	Average	Annual	Deviation	MD	CD	MD	MD	CD	MD	Crop	MD	CD
Francisville	30/yr											
2007	37.4	46.16	7.76	0.12	2.28	95	NA	NA	NA	Corn	188	186
2008	37.4	43.56	6.16	2.49	2.07	-18				Corn	251	253
2009	37.4	41.97	4.57	4.57	2.75	-50				NA	NA	NA
Reynolds	30/yr											
2006	38.7									Corn	185	208
2007	38.7	27.78	-10.92	6.4	9.2	36	15.19	19.85	27	Corn	186	184
2008	38.7	42.77	4.07	11.5	13.6	17	40.71	45.73	12	Corn	202	202
2009	38.7	34.38	-4.32	11.1	10.1	-9	17.35	17.32	0	Corn	175	164
Wolcott	30/yr											
2006	38.7									Corn	192	187
2007	38.7	27.88	-10.82	16.3	16.1	-1	39.54	35.24	-12	Soyb	58	54
2008	38.7	45.03	6.33	11.2	13.2	17	38.04	37.54	-1	Corn	169	178
2009	38.7	43.35	4.65	13	13.6	4	17.09	16.88	-1	Soyb	57	60
Crawfordsville	30/yr											
2007	39.8	34.43	-5.37	17.6	18.6	6	35.2	31.53	-11	Corn	241	231
2008	39.8	48.99	9.19	17.8	20.2	13	39.31	43.81	11	Corn	136	129
2009	39.8	50.72	10.92	19.3	14.8	-26	29.9	23.44	-24	Corn	220	199

Iowa CIG Results

MD-Managed Drainage CD-Conventional Drainage

	Precipitation/inches			In/outflows/Type of system		% Reduction	Nitrate Loss lbs/acre		% Reduction	Yields		
Site/yr	Average	Annual	Deviation	MD	CD	MD	MD	CD	MD	Crop	MD	CD
Hamilton Cty	10/yr											
2007	34.6	41.3	6.7	11.43	10.98	NA	13.7	11.5	NA	NA		
2008	34.6	41.4	6.8	11.1	11	**NA**	12.5	8.4	NA	NA		
2009	34.6	34.9	0.3	3.93	6.15	**NA**	9.4	11.6	NA	Corn		
Story City	40/yr											
2006	32.79	34.47	1.68	8.34	6.5	22	17.58	21.72	19	Corn	173.2	163.95
2007	32.79	35.37	2.58	17.31	11.66	33	23.57	38.84	39	Soyb	64.03	57.14
2008	32.79	42.51	9.72	15.33	12.04	21	33.48	39.64	16	Corn	191.16	204.13
2009/nine mo's	27.78	24.35	3.43	8.74	7.57	13	11.26	12.5	10	Soyb	60.07	59.49
Crawfordsville	10/yr											
2007	34.63	40.31	5.69	7.05	10.14	30	14.86	20.87	29	Corn/Soyb	170.6/55.9	178.5/57.8
2008	34.63	36.15	1.52	9.15	12.07	24	6.23	22.53	72	Corn/Soyb	168.2/47.6	171.6/46.9
2009/10 mo.	31.34	45.69	14.34	13.94	23.11	40	14.29	14.53	2	Corn/Soyb	152.5/63.4	169.9/67.4
Pekin	10/yr											
2005	35.92	24.93	-10.99	1.39	3.58	61	NA	NA		Corn/Soyb	135.0/43.5	136.4/38.3
2006	35.92	22.84	-13.08	1.15	3.47	67	0.74	1.22	39	Corn/Soyb	NA	NA
2007	35.92	44.38	8.46	8.65	18.69	54	16.62	41.97	60	Corn/Soyb	141.7/45.7	139.3/43.7
2008	35.92	34.81	-1.11	6.25	16.6	62	10.65	28.58	63	Corn/Soyb	223.4/44	228.1/41.8
2009/11 mo.	34.46	36	1.54	13.65	25.29	46	2.18	10.13	78	Soyb	55.3	57.7

Ohio CIG Results

MD-Managed Drainage CD-Conventional Drainage

	Precipitation/inches			In/outflows/Type of system		% Reduction	Nitrate Loss lbs/acre		% Reduction	Yields		
Site/yr	**Average**	**Annual**	**Deviation**	**MD**	**CD**	**MD**	**MD**	**CD**	**MD**	**Crop**	**MD**	**CD**
Napoleon	**30/yr**											
2007	34.7											
2008	34.7											
2009	34.7											
Lakeview	**30/yr**											
2007	38.7									Popcorn	194.1	197.7
2008	38.7									Soyb		
2009	38.7											
Dunkirk	**30/yr**											
2007	35.2											
2008	35.2											
2009	35.2											
Defience	**30/yr**											
2007	35.2											
2008	35.2											
2009	35.2											

Minnesota CIG Results

MD-Managed Drainage CD-Conventional Drainage

	Precipitation/inches			In/outflows/Type of system		% Reduction	Nitrate Loss lbs/acre		% Reduction	Yields		
Site/yr	**Average**	**Annual**	**Deviation**	**MD**	**CD**	**MD**	**MD**	**CD**	**MD**	**Crop**	**MD**	**CD**
Dundas	**30/yr**											
2007*	31.64	8.6	-23.04	NA	NA					NA	NA	NA
2008	31.64	21	-10.64	2.37	2.56	7	4.11	6.54	37	Corn	185	180
2009	31.64	25.22	-6.42	0.29	0.35	17	1.55	4.47	65	Soyb	54	54
Hayfield	**30/yr**											
2007*	30.14	11.59	-18.55	NA	NA					Corn	204	204
2008	30.14	15.7	-14.44	8.1	7.4	-9	39.4	39.2	-1	Soyb	51	57
2009	30.14	24.55	-5.59	3.3	3.8	13	9.7	8.7	-11	Corn	207	197
Wilmont	**30/yr**											
2007*	27.79	7.56	-20.23	NA	NA					NA	NA	NA
2008	27.79	29.1	1.31	4.5	4.2	-7	12.3	13	5	Corn	168	173
2009	27.79	22.94	-7.36	0.6	2.4	75	0.02	8.4	98	Corn	173	175
Windom	**30/yr**											
2007*	29	NA		NA	NA					NA	NA	NA
2008	29	27	-2	NA	12.8	NA	NA	34.2	NA	Soyb	49	48
2009	29	27.37	-1.63	1.8	6.1	60	2.7	6.3	60	Corn	187	187

* Precipitation over cropping season April 1 - October 31

Illinois CIG Results

MD-Managed Drainage CD-Conventional Drainage

	Precipitation/inches			In/outflows/Type of system		% Reduction	Nitrate Loss lbs/acre		% Reduction	Yields		
Site/yr	**Average**	**Annual**	**Deviation**	**MD**	**CD**	**MD**	**MD**	**CD**	**MD**	**Crop**	**MD**	**CD**
Hume #1	**30/yr**											
2006	38.76	41.86	3.1	NA	NA	NA	NA	NA	NA	Soyb	60.2	57.2
2007	38.76	33.27	-5.49	NA	NA	NA	NA	N	NA	Corn	184.5	187.6
2008	38.76	53.36	14.6	11.26	22.88	50.8	33.03	95.67	65.47	Soyb	47.9	48
2009	38.76	53.12	14.36	11.58	31.35	63.05	19	100.63	81.12	Corn	184.1	174.6
Hume #2	**30/yr**											
2006	38.76	41.86	3.1	NA	NA	NA	NA	NA	NA	Soyb	59	53.7
2007	38.76	33.27	-5.49	NA	NA	NA	NA	NA	NA	Corn	189.4	182.3
2008	38.76	53.36	14.6	14.83	29.74	50.15	NA	NA	NA	Soyb	52.3	51.2
2009	38.76	53.12	14.36	8.39	24.16	65.27	17.71	82.34	78.49	Corn	181.6	186.7
Barry	**30/yr**											
2006	38.44	29.47	-8.97	NA	NA	NA	NA	NA	NA	**Corn**	122.9	140.6
2007	38.44	27.31	-11.13	NA	NA	NA	NA	NA	NA	Corn	123.5	135.7
2008	38.44	49.5	11.06	0.81	21.22	96.2	NA	NA	NA	Corn	168	160.3
2009	38.44	46.91	8.47	1.58	8.58	81.55	3.58	17.44	79.48	NA	NA	NA
Enfield	**30/yr**											
2006	45	45.12	0.12	NA	NA	NA	NA	NA	NA	**Corn**	**192.6**	**197.7**
2007	45	39.6	-5.4	NA	NA	NA	NA	NA	NA	Soyb	60.8	50.5
2008	45	47.05	2.05	24.9	32.6	23.62	NA	NA	NA	Corn	186.2	194.8
2009	45	51.56	6.56	8.46	13.13	35.56	14.07	21.73	35.27	NA	NA	NA

NA is entered where no data was available due to project start-up or installation timing, or data missing because of malfunction, Notes are provided in main document.

Recommendations

It is feasible to retrofit existing drainage systems up to 0.5% grade. Estimates of drained acres that will accommodate DWM could exceed 10 million acres or more.

If DWM designs were incorporated into the designs of new drainage systems or drainage systems that are being replaced because they are deteriorating, a greater percentage of each field could be utilized. By placing the drainage mains up the slope and installing the lateral drains across the slope, and using new, high-technology in-ground controls to manage the water table, DWM could be installed on grades up to 2%. This would increase the estimated drained acreage by an additional 50 million acres. The estimated cost of designing and installing a new system for DWM is 10% or less of the total drainage project cost. The economics of including upgrades to new system on a per-unit cost of nitrate reduction should be included in cost-share funding.

The size of the main dictates the coefficient of a drainage system, but the lateral spacing of the drainage pipes determine the level of the water table. One area of concern is the perched water table halfway between the lateral drainage lines. The perched water table can be reduced by using a smaller diameter pipe spaced closed together without changing the drainage coefficient. This would create more uniformity and allow producers to change the control settings to as much as 10 days prior to or after field operations, thereby reducing the total amount of outflows.

Though DWM can be used as a stand alone practice, producers could use it as one of a suite of drainage management practices that can also include constructed or natural wetlands, saturated buffers, bioreactors and crop production practices that can reduce nutrients and flows from the landscape. Many of these practices can be installed at the edges of fields to reduce impacts on cropping.

In order to provide the technical support needed to assist landowners and producers, a network of private and public trained personnel needs to be a high priority for implementation.

ADMC's Conclusions

The three-year DWM demonstration program yielded important insight on the environmental benefits and the practicalities of controlling drainage, as well as outreach efforts that made more than 1 million impressions on farmers, drainage experts and members of the environmental community through farm forums, outreach and publications. Even challenges encountered in quantifying yield effects provided important perspective on future study and observation of the practice.

We are significantly closer to understanding how drainage water management can help address nutrient enrichment problems in surface waters throughout the Mississippi River watershed and into the Gulf of Mexico. Such understanding will provide invaluable guidance in the development of policies and programs that incentivize drainage water management.

DEMONSTRATION FIELD SITES

Indiana Site Descriptions

Table 1. Indiana site descriptions.

Sites	Site 1	Site 2	Site 3	Site 4
Description	**Francesville**	**Reynolds**	**Wolcott**	**Crawfordsville**
Managed drainage (acres)	37.7*(South)	23.5 (North)	8.0 (South)	26 (North)
Conventional drainage (acres)	40.3 (North)	15.2 (South)	6.7 (North)	34 (South)
Soil types	Strole silt loam, Milford silty clay loam, and Medaryville fine sandy loam	Rensselaer variant loam	Rensselaer loam, Wolcott clay loam, and Gilford fine sandy loam	Ragsdale silty clay loam, Reeseville silt loam, and Reeseville-Fincastle silt loam
Watershed name	Mosley Ditch	Hoagland Ditch	Hoagland Ditch	Indian Creek
10 or 30 year precipitation averages	37.4 in	38.7 in	38.7 in	39.8 in
Installation date of system month/ year	1972, 1982, 1984, 1998	unknown	unknown	2003
Depth of tile	3 – 4 ft	3 – 4 ft	3 – 4 ft	2.5 – 3.5 ft
Drainage coefficient (in.)	unknown	unknown	unknown	unknown
Tile spacing	70 or 75 ft	140 ft	75 ft	70 ft
New or retrofit system	Retrofit	Retrofit	Retrofit	Retrofit
Installation date of control structure	June 2007	March 2005	March 2005	November 2004
Laterals on the contour	No	No	No	No

*During the first 10 months of the project (June 2007 to March 2008), the north field was managed and the south field was conventional. They were switched to better manage the water table, as described below.

Figure 1. Francesville site soil map.

Figure 2. Francesville site tile map.

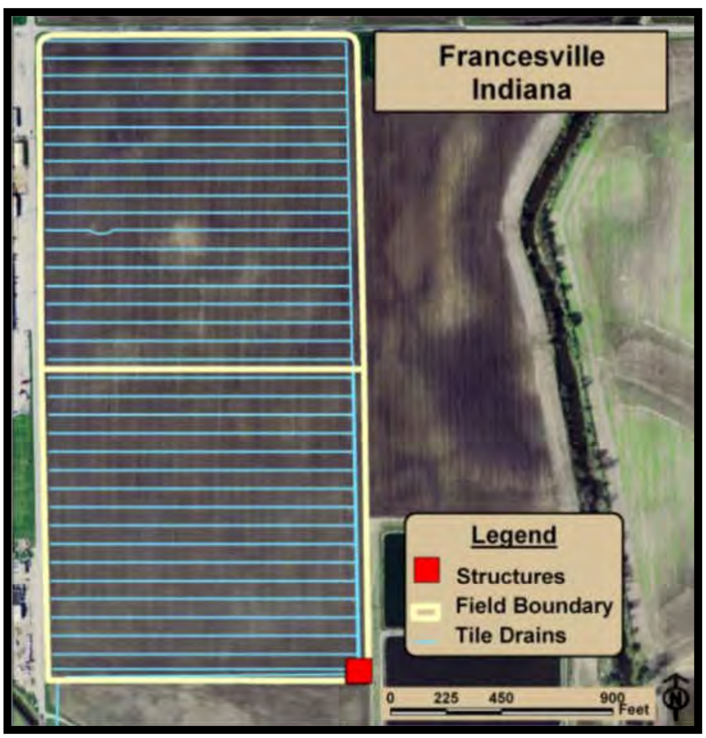


Figure 3. Francesville site topographical map.

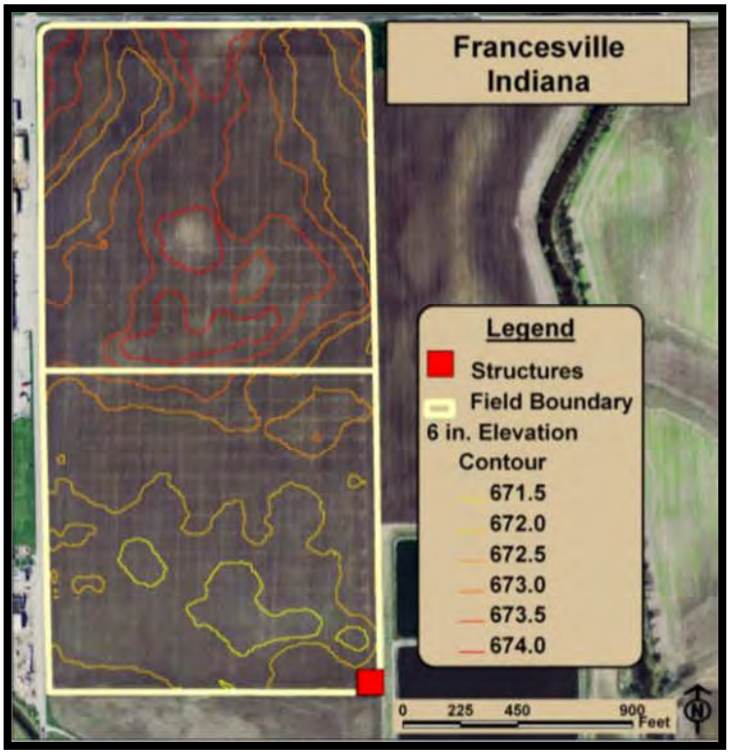


Figure 4. Francesville site aerial map.

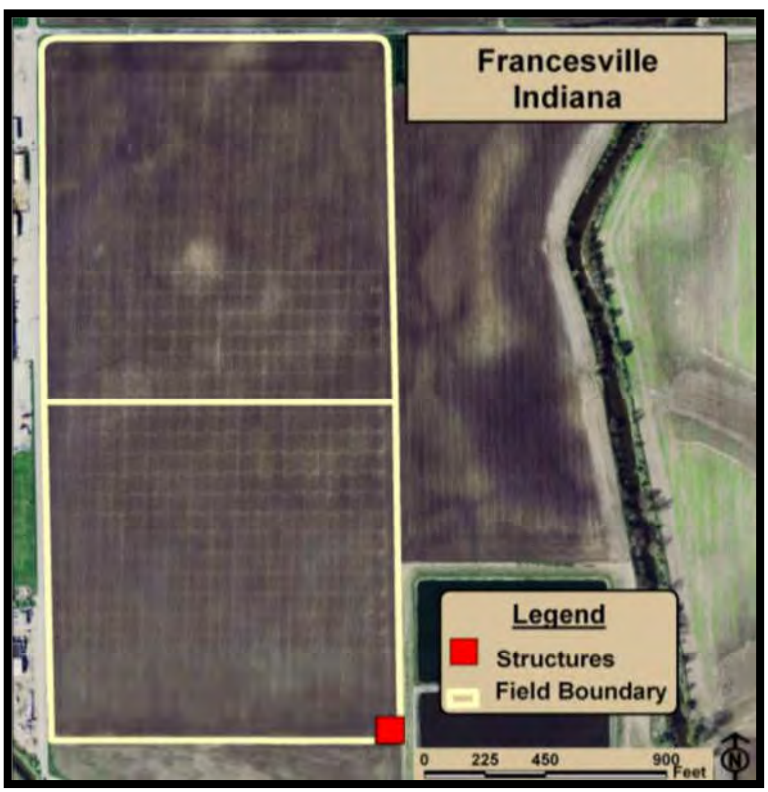


Figure 5. Reynolds site soil map.

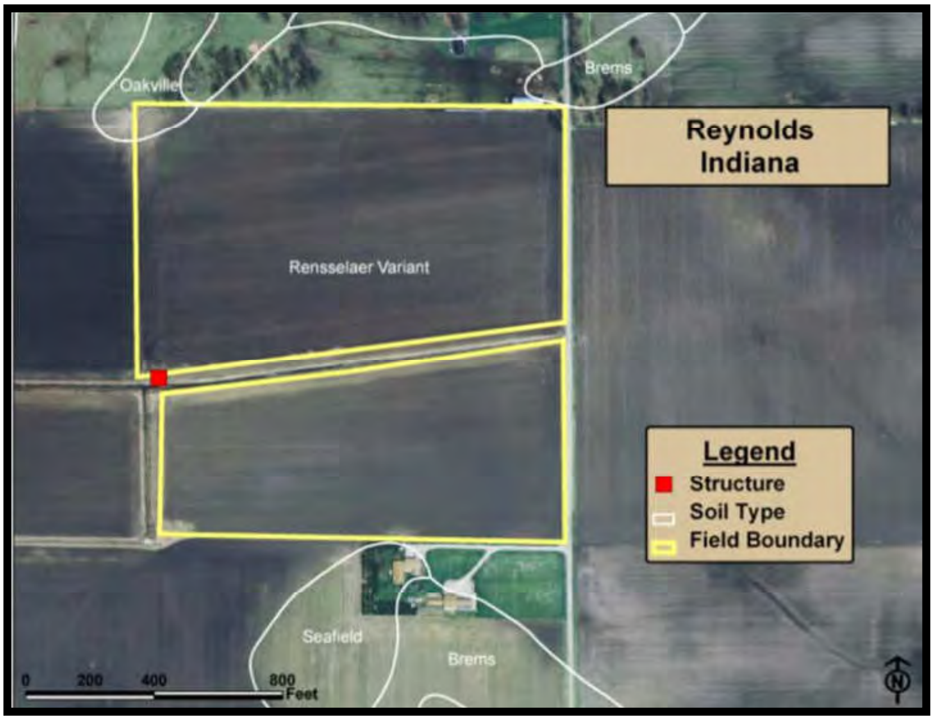


Figure 6. Reynolds site tile map.

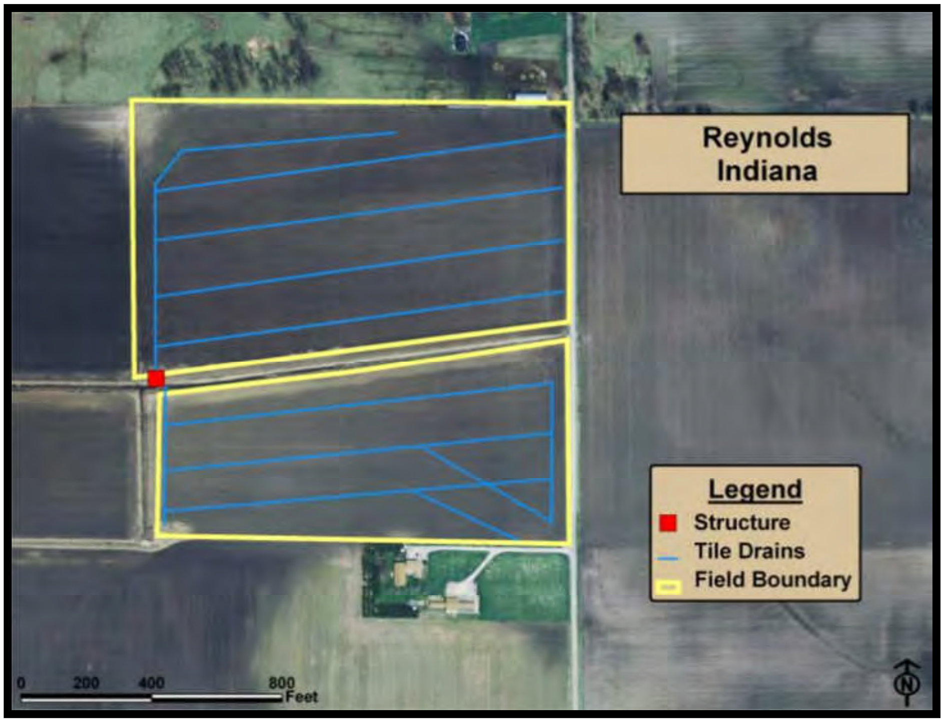


Figure 7. Reynolds site topographical map.

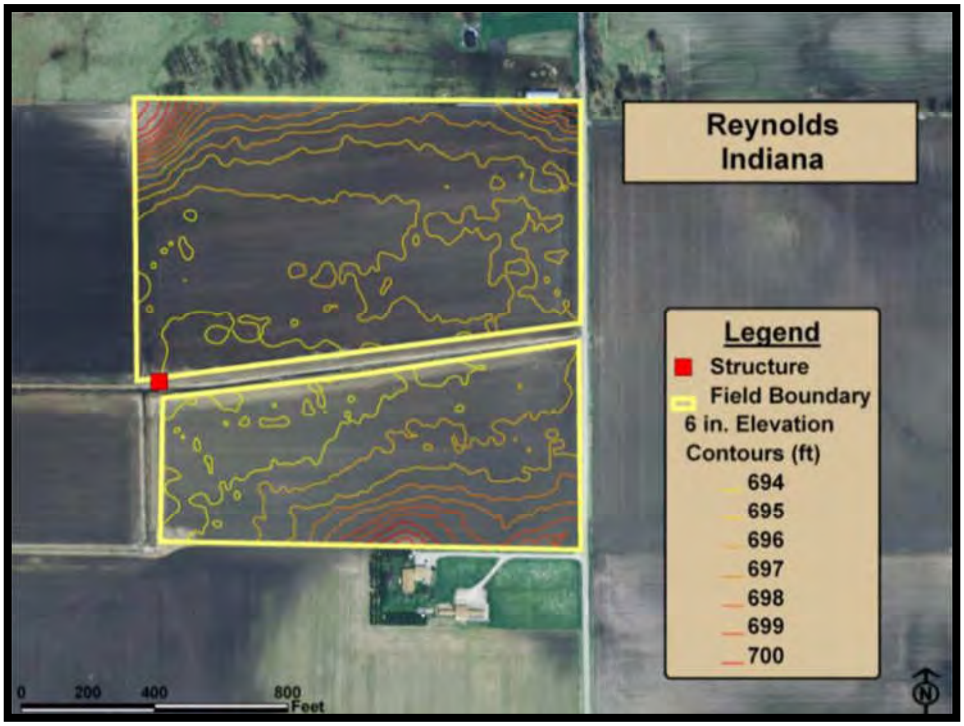


Figure 8. Reynolds site aerial map.

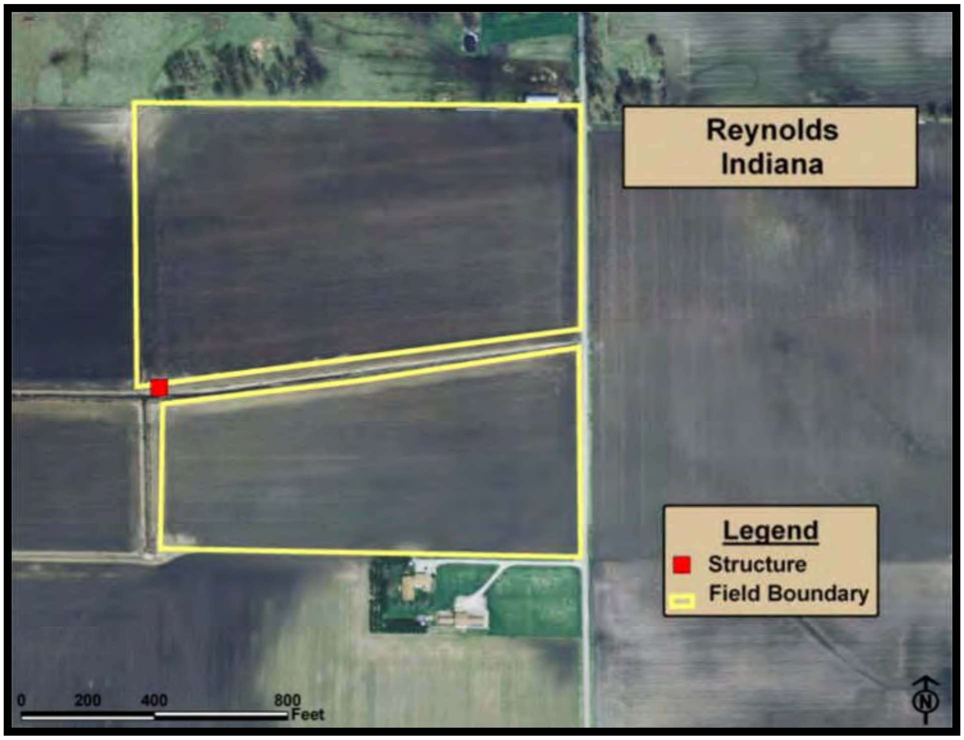


Figure 9. Wolcott site soil map.

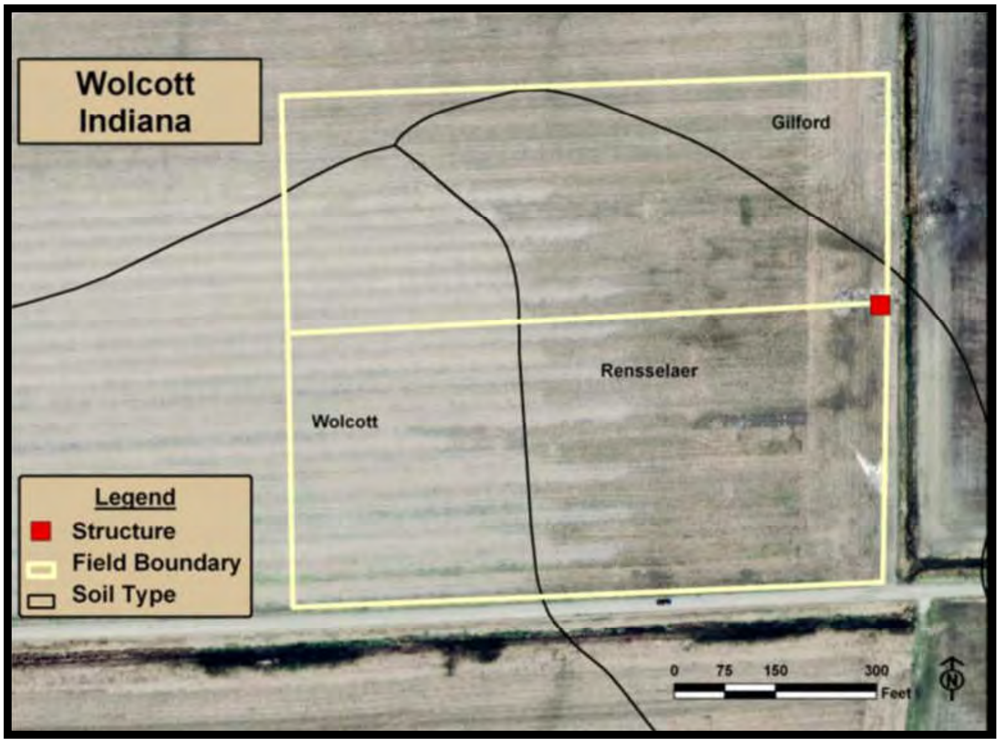


Figure 10. Wolcott site tile map.

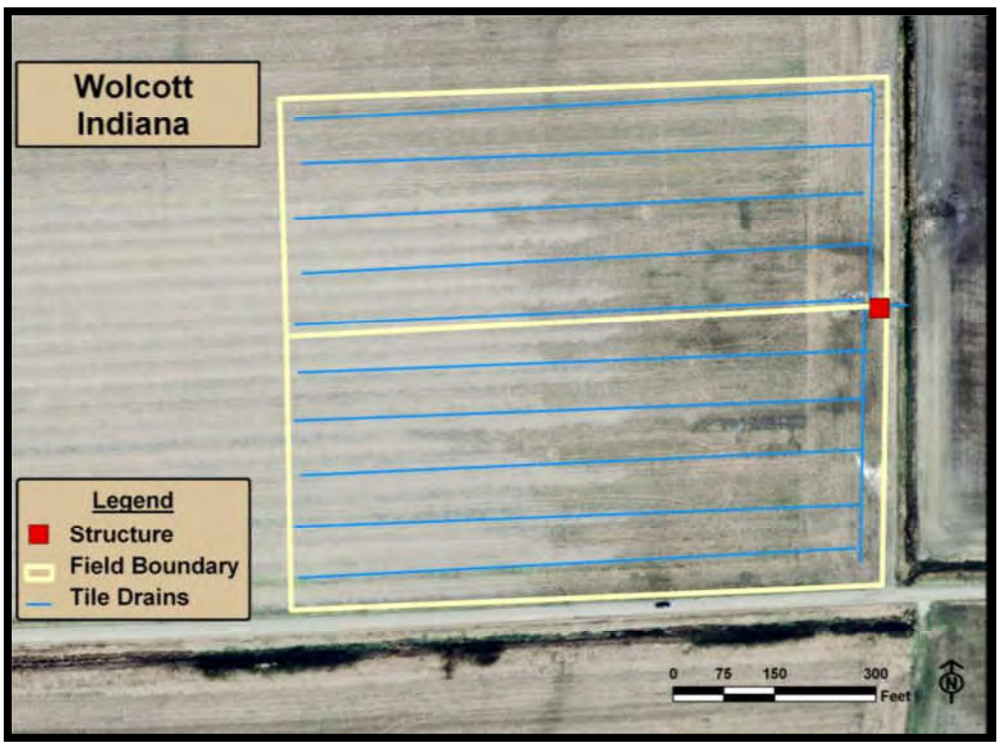


Figure 11. Wolcott site topographical map.

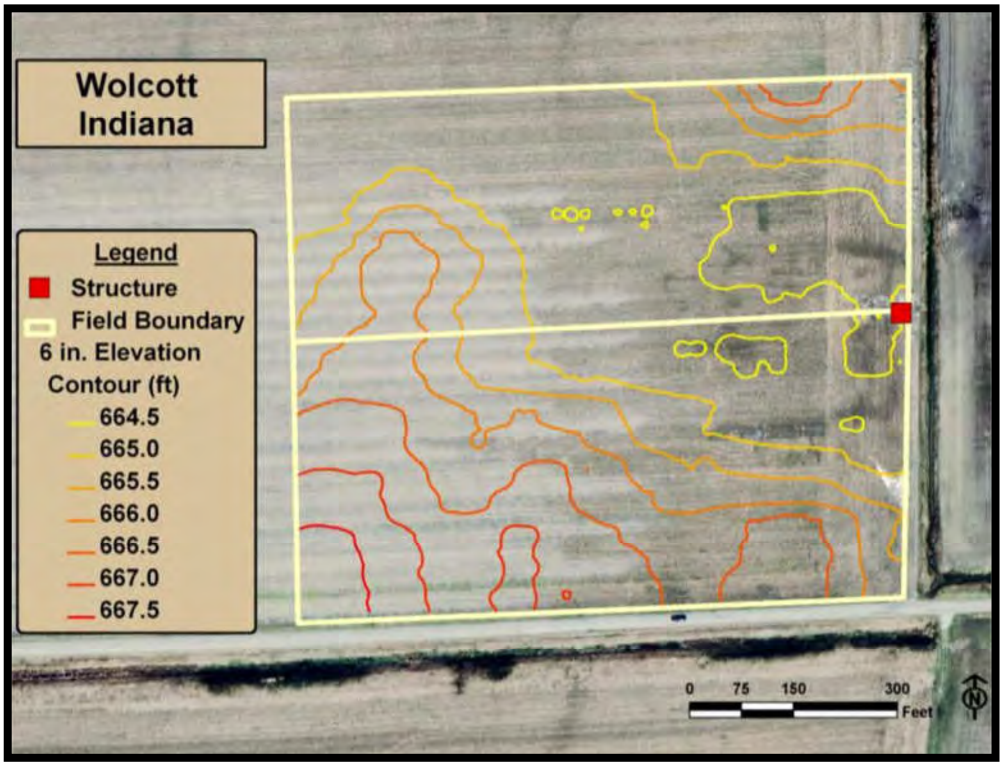


Figure 12. Wolcott site aerial map.

Figure 13. Crawfordsville site soil map.

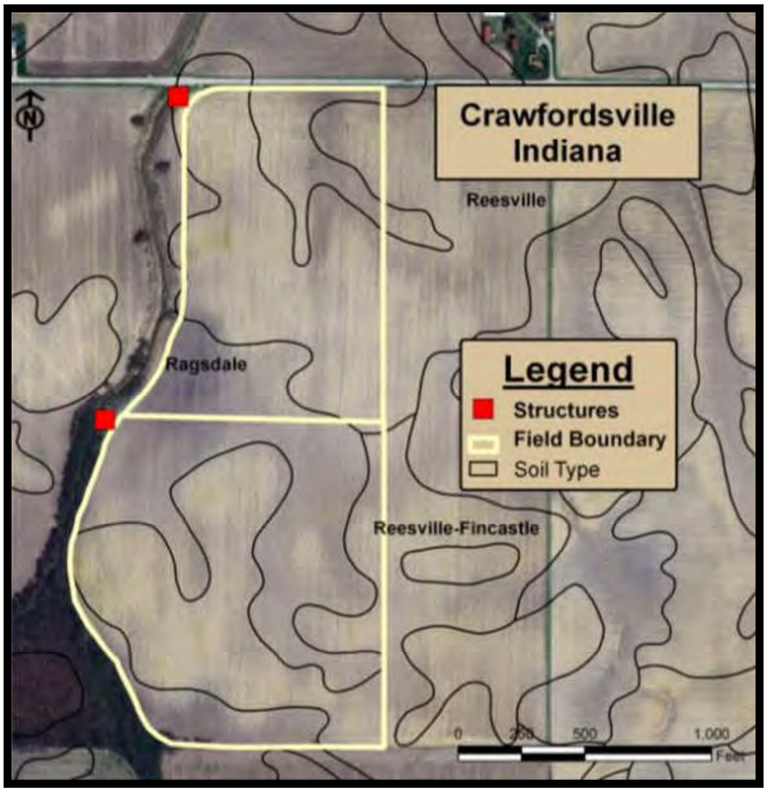


Figure 14. Crawfordsville site tile map.

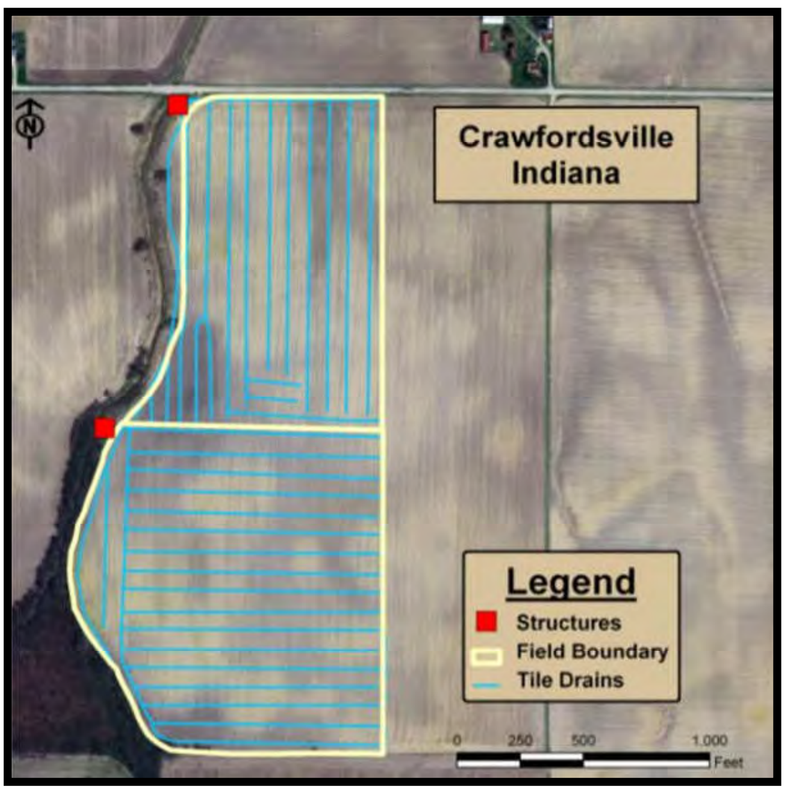


Figure 15. Crawfordsville site topographical map.

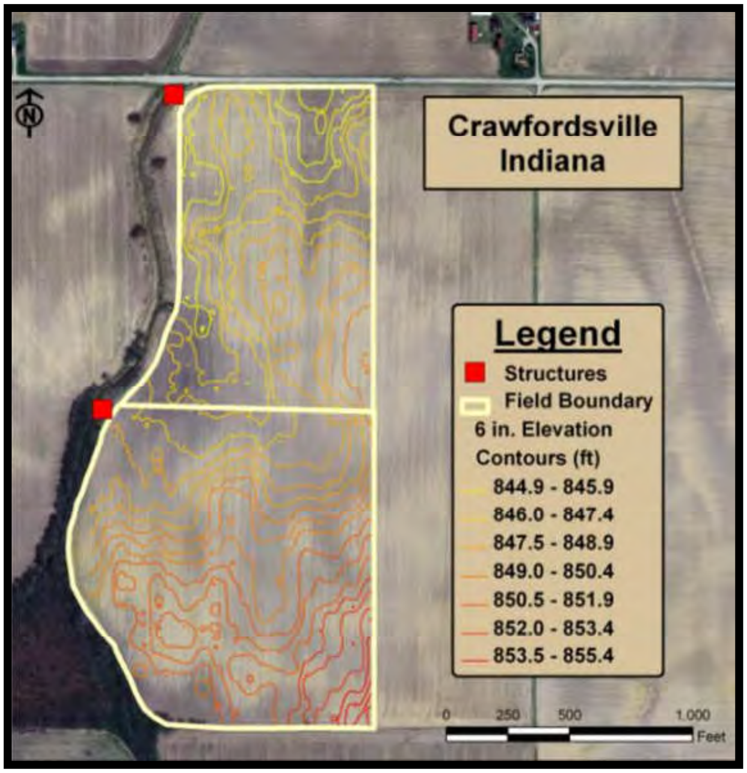
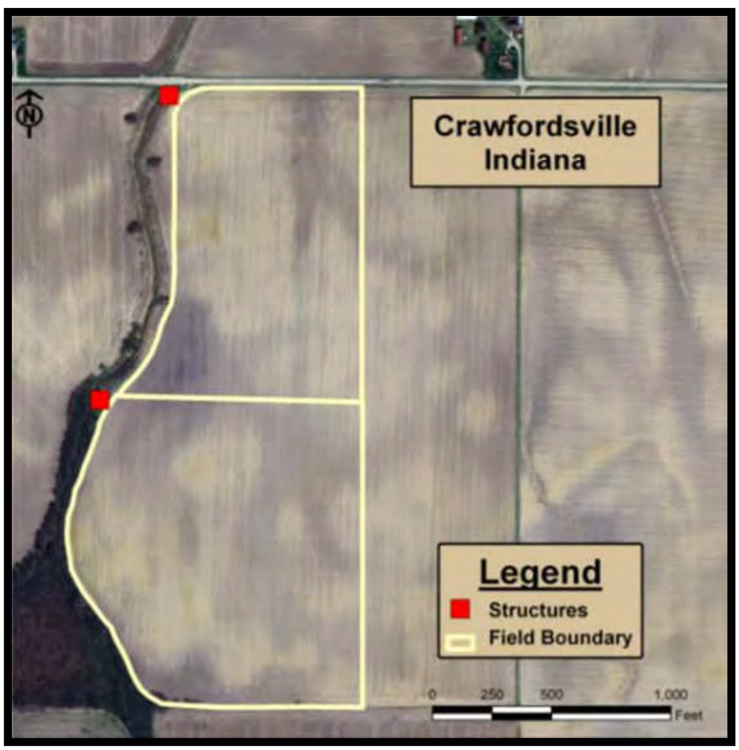


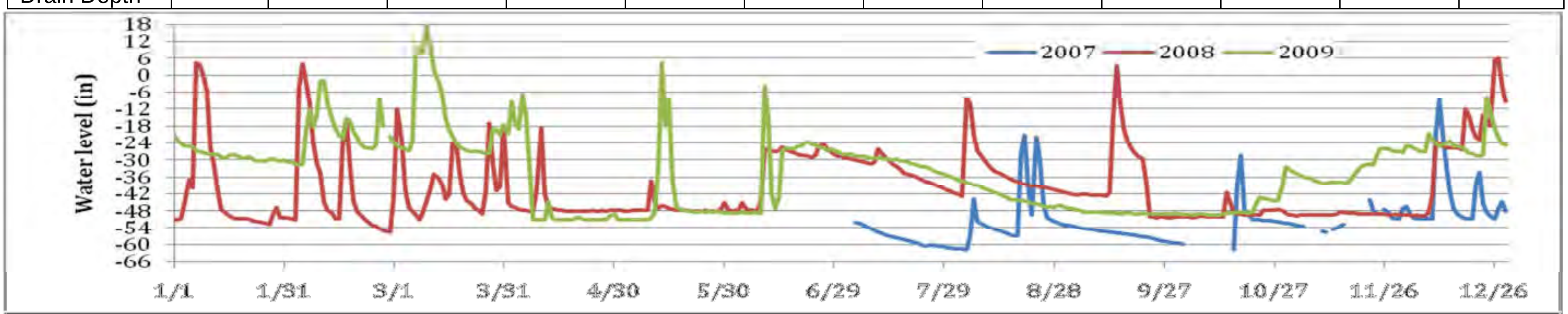
Figure 16. Crawfordsville site aerial map.



Indiana Water Management Plan

Figure 17. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Francesville.

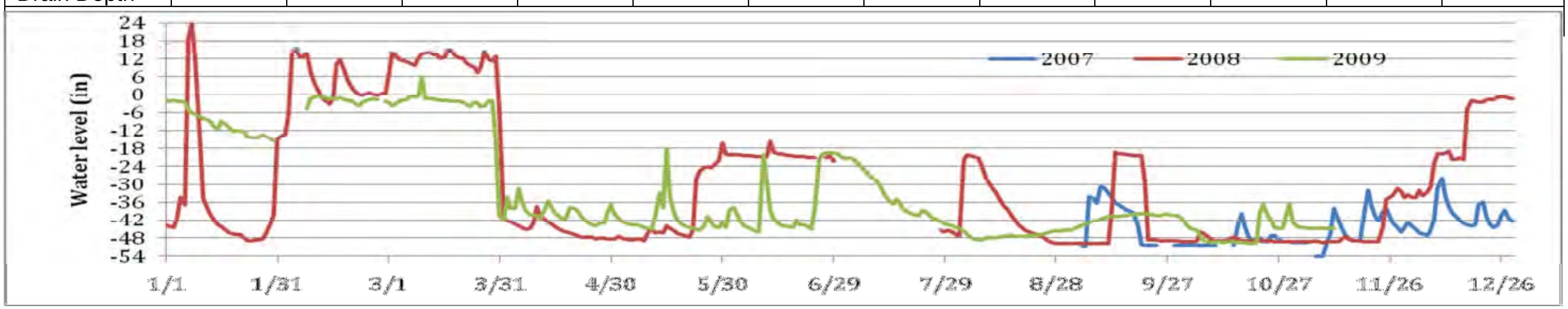
Crop:	Corn - 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	-	-	-	-	-	-	27”	27”	27”	27”	27”	3”
2	-	-	-	-	-	-	27”	27”	27”	27”	3”	3”
3	-	-	-	-	-	27”	27”	27”	27”	27”	3”	3”
4	-	-	-	-	-	27”	27”	27”	27”	27”	3”	3”
Crop:	Corn - 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	3”	3”	3”	51”	51”	17”	17”	17”	17”	51”	51”	51”
2	3”	3”	3”	51”	51”	17”	17”	17”	17”	51”	51”	5”
3	3”	3”	3”	51”	51”	17”	17”	17”	17”	51”	51”	5”
4	3”	3”	3”	51”	17”	17”	17”	17”	51”	51”	51”	5”
Crop:	Corn - 2009											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	5”	5”	5”	5”	51”	51”	22”	22”	22”	22”	22”	22”
2	5”	5”	5”	51”	51”	22”	22”	22”	22”	22”	22”	22”
3	5”	5”	5”	51”	51”	22”	22”	22”	22”	22”	22”	5”
4	5”	5”	5”	51”	51”	22”	22”	22”	22”	22”	22”	5”
Drain Depth												



All elevations are relative to the lowest point in the field. The north field was managed June 2007 - March 2008, after which the south field was managed.

Figure 18. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Reynolds.

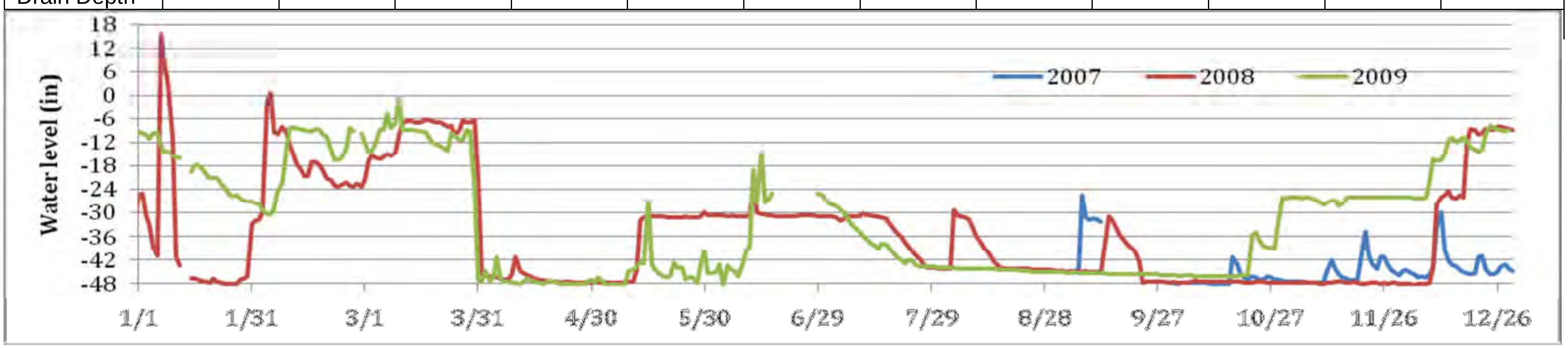
Crop:	Corn - 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	54”	54”	54”	54”	54”	23”	23”	23”	23”	54”	54”	54”
2	54”	54”	54”	54”	54”	23”	23”	23”	23”	54”	54”	54”
3	54”	54”	54”	54”	54”	23”	23”	23”	23”	54”	54”	54”
4	54”	54”	54”	54”	23”	23”	23”	23”	54”	54”	54”	54”
Crop:	Corn - 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	54”	+18”	+18”	54”	54”	23”	23”	23”	23”	54”	54”	54”
2	54”	+18”	+18”	54”	54”	23”	23”	23”	23”	54”	54”	54”
3	54”	+18”	+18”	54”	54”	23”	23”	23”	23”	54”	54”	54”
4	54”	+18”	+18”	54”	23”	23”	23”	23”	23”	54”	54”	6”
Crop:	Corn - 2009											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6”	6”	6”	54”	54”	54”	23”	23”	23”	23”	47”	6”
2	6”	6”	6”	54”	54”	54”	23”	23”	23”	23”	47”	6”
3	6”	6”	6”	54”	54”	54”	23”	23”	23”	23”	47”	6”
4	6”	6”	6”	54”	54”	23”	23”	23”	23”	47”	6”	6”
Drain Depth												



Comments All elevations relative to lowest point in the field.

Figure 19. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Wolcott.

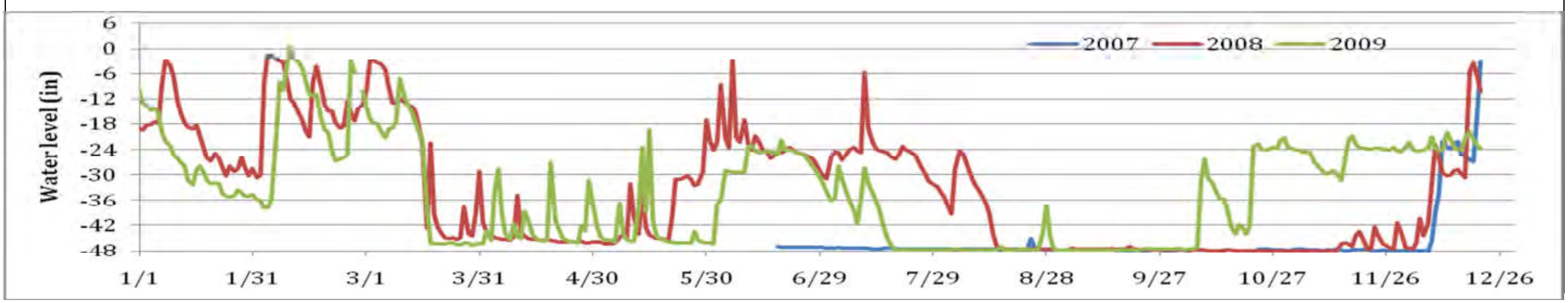
Crop:	Soybeans - 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	50”	50”	50”	50”	50”	31”	31”	31”	31”	50”	50”	50”
2	50”	50”	50”	50”	50”	31”	31”	31”	31”	50”	50”	50”
3	50”	50”	50”	50”	50”	31”	31”	31”	31”	50”	50”	50”
4	50”	50”	50”	50”	31”	31”	31”	31”	50”	50”	50”	50”
Crop:	Corn - 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	50”	7”	7”	50”	50”	31”	31”	31”	31”	50”	50”	50”
2	50”	7”	7”	50”	50”	31”	31”	31”	31”	50”	50”	50”
3	50”	7”	7”	50”	31”	31”	31”	31”	31”	50”	50”	9”
4	50”	7”	7”	50”	31”	31”	31”	31”	31”	50”	50”	9”
Crop:	Soybeans - 2009											
Example	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
week												
1	9”	9”	9”	50”	50”	50”	26”	26”	26”	26”	26”	9”
2	9”	9”	9”	50”	50”	50”	26”	26”	26”	26”	26”	9”
3	9”	9”	9”	50”	50”	26”	26”	26”	26”	26”	26”	9”
4	9”	9”	9”	50”	50”	26”	26”	26”	26”	26”	9”	9”
Drain Depth												



Comments All elevations relative to lowest point in field.

Figure 20. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Crawfordsville.

Crop:	Corn - 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6”	6”	6”	48”	48”	24”	24”	24”	24”	48”	48”	48”
2	6”	6”	6”	48”	48”	24”	24”	24”	24”	48”	48”	48”
3	6”	6”	6”	48”	24”	24”	24”	24”	48”	48”	48”	6”
4	6”	6”	48”	48”	24”	24”	24”	24”	48”	48”	48”	6”
Crop:	Corn - 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6”	6”	6”	48”	48”	24”	24”	24”	24”	48”	48”	6”
2	6”	6”	6”	48”	48”	24”	24”	24”	24”	48”	48”	6”
3	6”	6”	48”	48”	48”	24”	24”	24”	24”	48”	6”	6”
4	6”	6”	48”	48”	24”	24”	24”	24”	24”	48”	6”	6”
Crop:	Corn - 2009											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6"	6"	6"	48"	48"	48"	24"	24"	24"	24"	24"	24"
2	6"	6"	6"	48"	48"	24"	24"	24"	24"	24"	24"	24"
3	6"	6"	48"	48"	48"	24"	24"	24"	24"	24"	24"	6"
4	6"	6"	48"	48"	48"	24"	24"	24"	24"	24"	24"	6"
Drain Depth												



Comments All elevations relative to lowest point in field.

Comments on Water Management Plan

The Site 1 (Francesville) data in Fig. 17 illustrate a problem in holding water at this site. Originally the north half of the field was chosen to be the managed half, from June 2007 through March 2008. However the water level in the structure, after rising in response to precipitation, fell rapidly back to a depth of 48 to 60 inches. Because water could not successfully be held back on the north half, the control was switched to the south half. The graph from winter 2009 shows that the water levels were maintained higher (24 to 30 inches), supporting the decision to switch fields.

Sites 2 and 3 showed relatively constant, high water levels in the structure during February and March of the managed period. Water levels were also relatively constant near the control setting depth during the early growing season in 2008. The control was raised earlier in the growing season that year because of earlier planting, which contributed to more of an effect of drainage management.

Water levels at Site 4 appeared to vary more with time and did not remain at the managed setting as long. A leak in the structure may have had some influence on this. But it may also be due to the greater topographic differences within Site 4, providing a regional gradient for water flow. Both Sites 2 and 3 were flatter and surrounded by much flatter land, and it is likely that a regional water table may have also contributed to keeping water levels higher overall.

Indiana Cropping and Yield Data

Table 2a. Cropping and yield data for Site 1 (Francesville, Indiana).

		2006		2007		2008		2009	
Crop				Corn		Corn		Soybeans	
Variety				Beck 5366		DK 6342 VT3		Asgrow 3802	
Planting Date				5/1/07		5/4/08		5/28/09	
Row Spacing				30 in		30 in		15 in	
Tillage	**Conventional**			XXXXX		XXXXX			
	Conservation							XXXXX	
	No Till								
Nitrogen									
Fall N application	**Date**			none		none		none	
	Actual N#s/acre			none		none		none	
Pre-plant N application	**Date**			3/30/07		3/28/08		none	
	Actual N#s/acre			200		180		none	
Post-plant N application	**Date**			Spring 2007		6/26/08		Spring 2009	
	Actual N#s/acre			13.8		57		16.5	
Phosphorus	**Actual P#s/acre**			29		46		34	
Potash	**Actual K#s/acre**			100		none		100	
Herbicide	**oz/acre**			Lumax Moxy		44 oz. Roundup		44 oz. Roundup	
Insecticide	**oz/acre**			Force 3G 4.4#/acre		none		none	
Harvest date				Nov 7		Nov 12		Oct 18	
Drainage	MD= Managed drainage; CD = Conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield (dry)				188	186	251	253	55	54
Moisture				14	14	17	17	12	12
Comments				-North section was managed -Heavy rain right after planting		-South section was managed -June hail storm		-South section was managed -Very little rain in July/August	

Table 2b. Cropping and yield data for Site 2 (Reynolds, Indiana).

		2006		2007		2008		2009	
Crop		Corn		Corn		Corn		Corn	
Variety		unknown		Pioneer 33K42/Pioneer 33T59		Select 510 YG/VT/RW/RR2		Dekalb 63-42 VT3	
Planting Date		unknown		4/24/07		4/24/08		5/23/09	
Row Spacing		30 in.		30 in.		30 in.		30 in.	
Tillage	**Conventional**								
	Conservation	Fall - Chisel		Fall - Chisel		Fall - Chisel		Fall - Chisel	
	No Till								
Nitrogen									
Fall N application	**Date**	10/26/05		Fall 2006		Fall 2007		none	
	Actual N#s/acre	200		26		234		none	
Pre-plant N application	**Date**	unknown (starter)		none		none		5/23/09 (starter)	
	Actual N#s/acre	3.3		none		none		2.3	
Post-plant N application	**Date**	Spring 2006		Spring 2007		Spring 2008		6/6/09	
	Actual N#s/acre	30		243		30		200	
Phosphorus	**Actual P#s/acre**	41		29		none		3.5	
Potash	**Actual K#s/acre**	2.7		74		none		none	
Herbicide	**oz/acre**	unknown		Lexar – 64 oz Liberty – 32 oz		Confidence 54 oz Cornerstone 32oz		Status 4oz Cornerstone 32oz	
Insecticide	**oz/acre**	none		none		none		none	
Harvest date		unknown		Sept 24		Oct 9		Nov 8	
Drainage	MD= Managed drainage; CD = Conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield (dry)		185	208	186	184	202	202	175	164
Moisture								22	23
Comments									

Table 2c. Cropping and yield data for Site 3 (Wolcott, Indiana).

		2006		2007		2008		2009	
Crop		Corn		Soybeans		Corn		Soybeans	
Variety		unknown		unknown		DK 63-42-VT3		Asgrow 3139RR	
Planting Date		5/10/06		unknown		5/9/08		5/22/09	
Row Spacing		30 in.		15 in.		30 in.		15 in.	
Tillage	**Conventional**								
	Conservation								
	No Till	XXXXX		XXXXX		XXXXX		XXXXX	
Nitrogen									
Fall N application	**Date**	Fall 2005		none		11/8/07		none	
	Actual N#s/acre	111		none		160		none	
Pre-plant N application	**Date**	5/10/06 (starter)		none		none		5/6/09 (manure)	
	Actual N#s/acre	57		none		none		94*	
Post-plant N application	**Date**	none		none		none		none	
	Actual N#s/acre	none		none		none		none	
Phosphorus	**Actual P#s/acre**	3.7		none		none		29	
Potash	**Actual K#s/acre**	1		none		250		73	
Herbicide	**oz/acre**	Atrazine 64oz Roundup 32oz		Roundup 32oz		Atrazine 64oz Roundup 32oz		Roundup 32oz	
Insecticide	**oz/acre**	none		none		none		none	
Harvest date		unknown		Oct 8		Nov 8		Oct 20	
Drainage	MD= Managed drainage; CD = Conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield (dry)		192	187	58	54	169	178	57	60
Moisture									
Comments								*Plant available N in manure	

Table 2d. Cropping and yield data for Site 4 (Crawfordsville, Indiana).

		2005		2006		2007		2008		2009	
Crop		Corn		Corn		Corn		Corn		Corn	
Variety		Becks 5399 CBRR		Becks 6722 CBRW		Becks 6722 CBRW		Becks 5684 VT3		Becks 5608 VT3	
Planting Date		4/20/05		4/22/06		4/20/07		4/30/08		4/25/09	
Row Spacing		20 in.		20 in		20 in		20 in		20 in	
Tillage	**Conventional**	Fall – disk ripper		Fall – disk ripper		Fall – disk ripper		Fall – disk ripper		Fall – disk ripper	
	Conservation										
	No Till										
Nitrogen											
Fall N application	**Date**	Fall 2004		Fall 2005		Fall 2006		Fall 2007		Fall 2008	
	Actual N#s/acre	78		29		30		Variable*		170	
Pre-plant N application	**Date**	Spring 2005		Spring 2006		Spring 2007		4/18/2008		Spring 2009	
	Actual N#s/acre	160		170		160		170		11	
Post-plant N application	**Date**	none		none		none		none		none	
	Actual N#s/acre	none		none		none		none		none	
Phosphorus	**Actual P#s/acre**	88		30		37		Variable*		5 or 55	
Potash	**Actual K#s/acre**	Yes		81		83		Variable*		0 or 100	
Herbicide	**oz/acre**	none		Durango 70oz Keystone 26oz		Durango 70oz Keystone 26oz		none		none	
Insecticide	**oz/acre**	Capture 34oz.		none		Headline 9oz. (fung)		Headline 9oz. (fung)		Headline 9oz. (fung)	
Harvest date		Oct 12-13		Oct 4		Sept 21		Oct 4		Oct 5	
Drainage	MD= Managed drainage; CD = Conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield (dry)		176	175	215	211	241	236	136	132	220	208
Moisture											
Comments	*Fertilizer application by Coop. We do not have exact rates at each location in the field.										

Iowa Site Descriptions

Table 3. Iowa site descriptions.

Sites	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Description	**Hamilton County**	**Story City**	**Crawfordsville**	**Pekin**
Managed drainage (acres)	31.6 ac	17.5 ac	14.3 ac	10.8 ac
Conventional drainage (acres)	38.3 ac	28.6 ac	3.3 ac	5.4 ac
Soil types	Kossuth, Browntown, Wacousta	Kossuth, Ottosen, Harps	Kalona, Mahaska, Taintor	Taintor
Watershed name	Squaw Creek	South Skunk River	Lower Iowa River	Skunk River
10 or 30 year precipitation averages	34.6 in	32.8 in	34.6 in	35.9 in
Installation date of system month/ year	1999, 2003	1992	2006	2002
Depth of tile	4 ft	4 ft	4 ft	4 ft
Drainage coefficient	3/8 – 1 1/8”	¾ - 1”	¾”	>¾” pumped outlet
Tile spacing	70 ft	90 & 120 ft	40 & 60 ft	80 ft
New or retrofit system	Retrofit	Retrofit	New	New
Installation date of control structure	Fall, 2006	Fall, 2005	Summer, 2006	Fall, 2002
Laterals on the contour (Yes or No)?	No	No	No	No

Figure 21. Hamilton County site soil map.

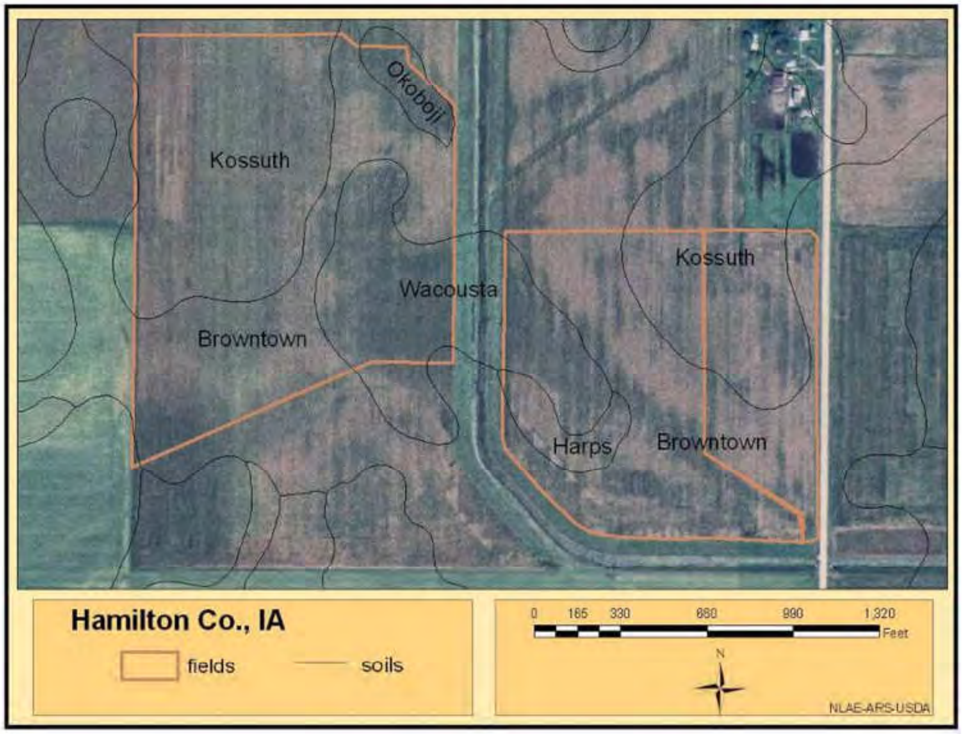


Figure 22. Hamilton County site tile map.

Figure 23. Hamilton County site topographical map.

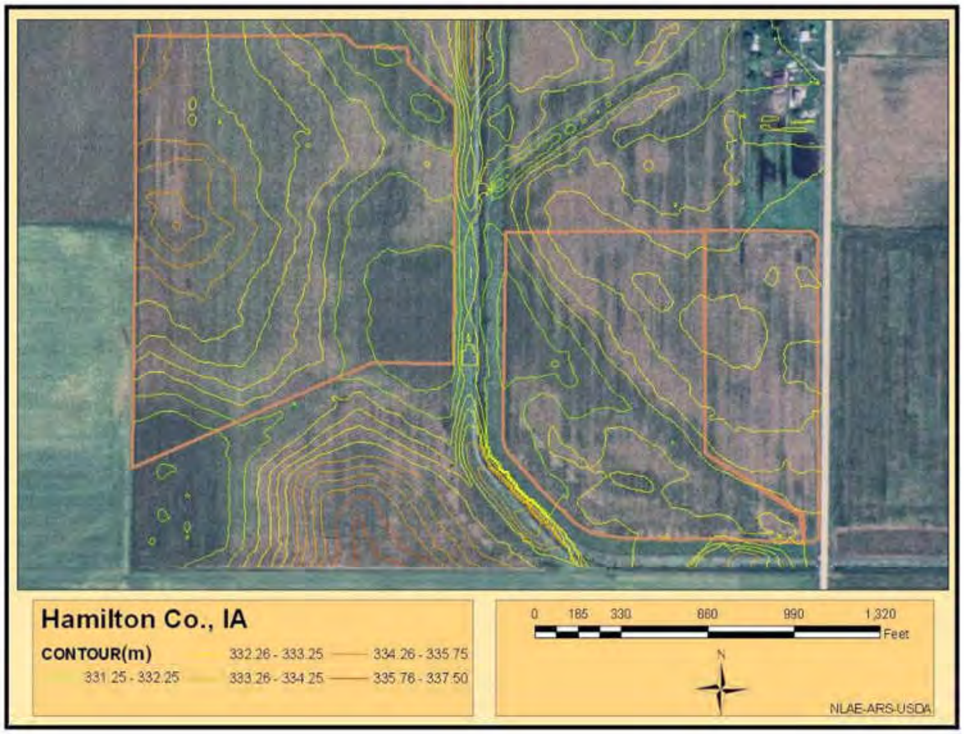


Figure 24. Hamilton County site aerial map.

Figure 25. Story City site soil map.

Figure 26. Story City site tile map.

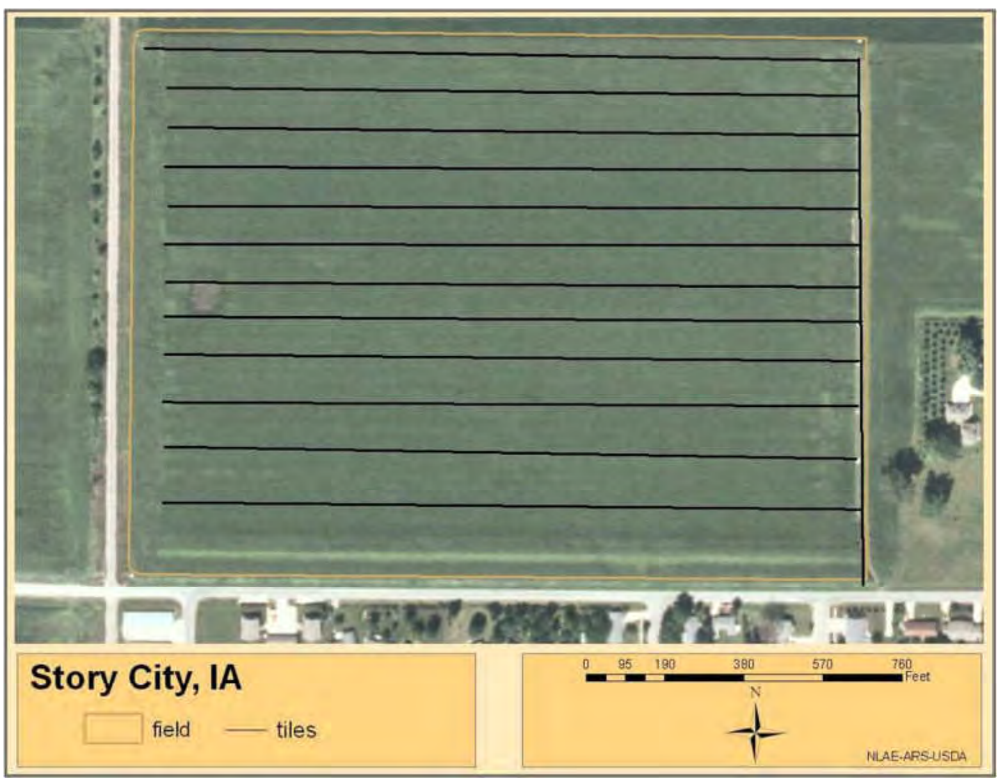


Figure 27. Story City site topographical map.

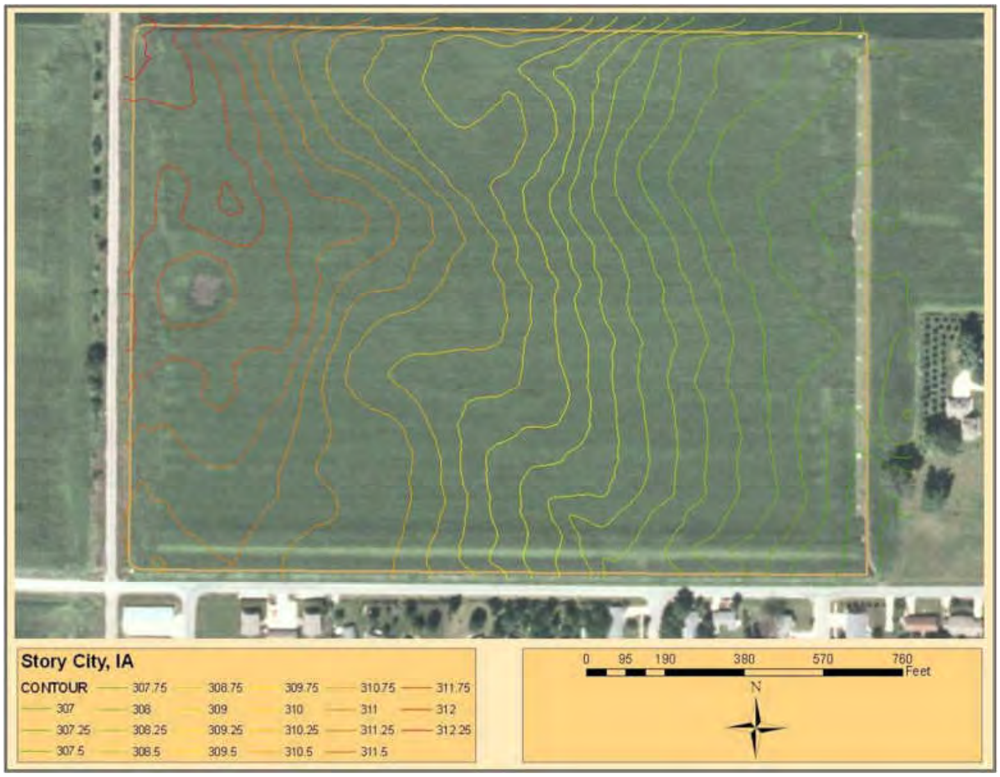


Figure 28. Story City site aerial map.

Figure 29. Crawfordsville site soil map.

Figure 30. Crawfordsville site tile map.

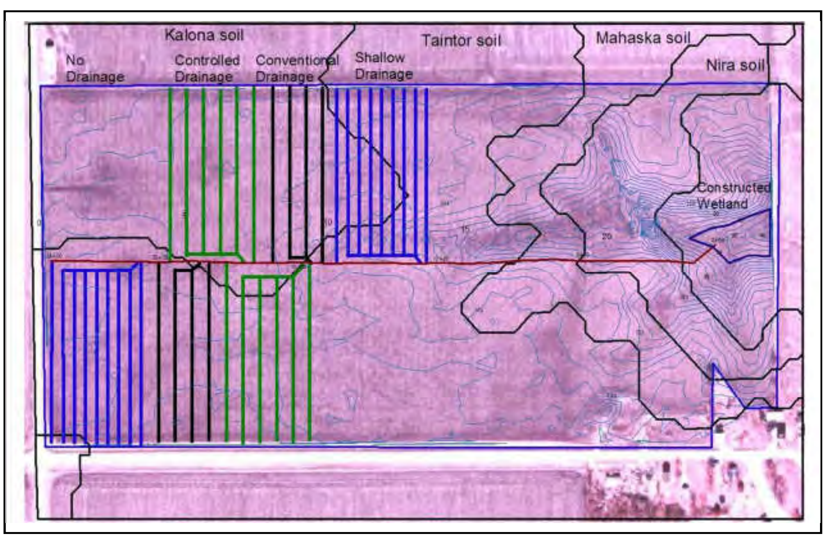


Figure 31. Crawfordsville site topographical map.

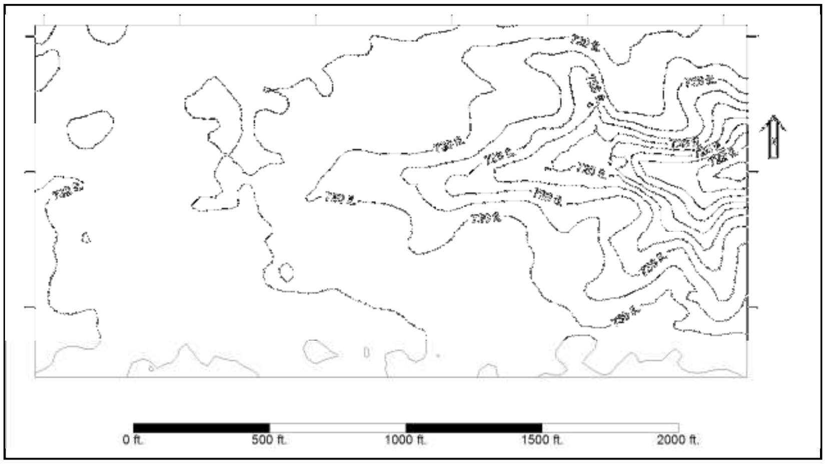


Figure 32. Crawfordsville site aerial map.

Figure 33. Pekin site soil map.

Figure 34. Pekin site tile map.

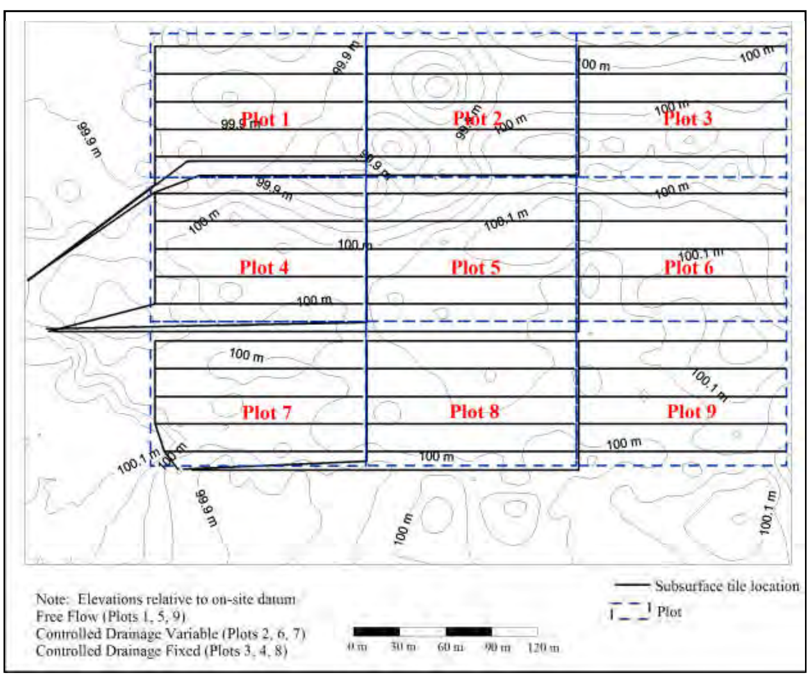


Figure 35. Pekin site topographical map.

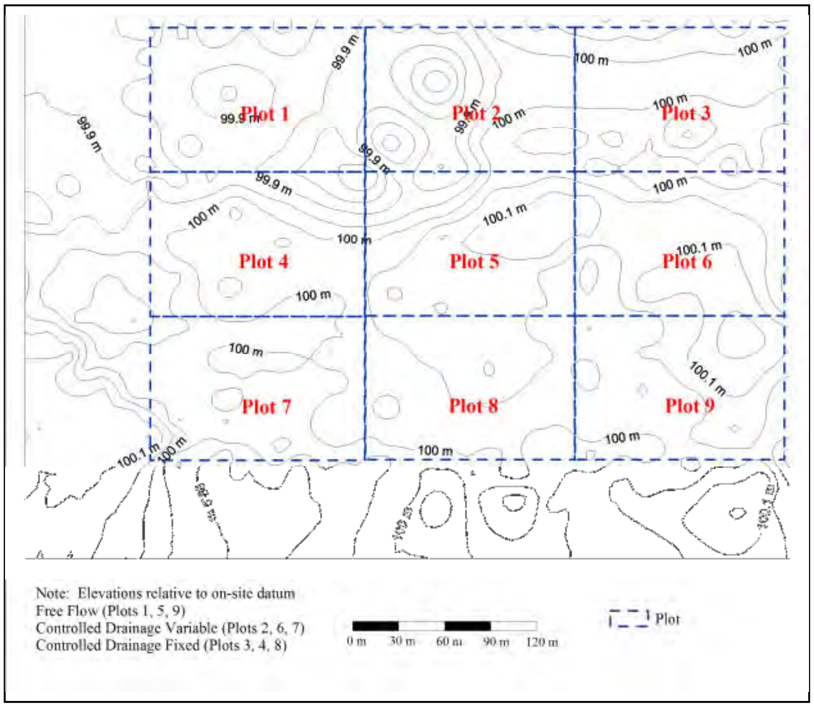
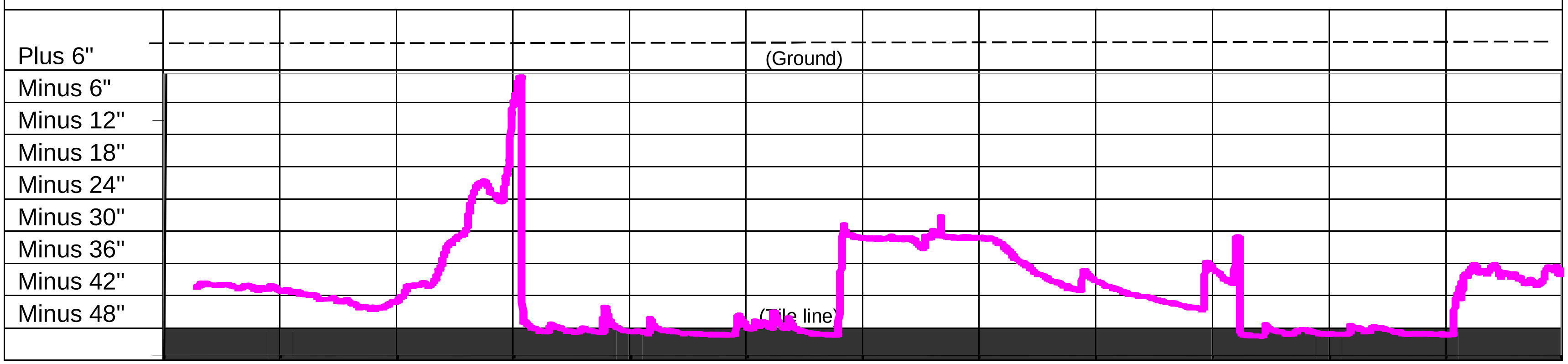


Figure 36. Pekin site aerial map.

Iowa Water Management Plan

Figure 37a. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Hamilton County.

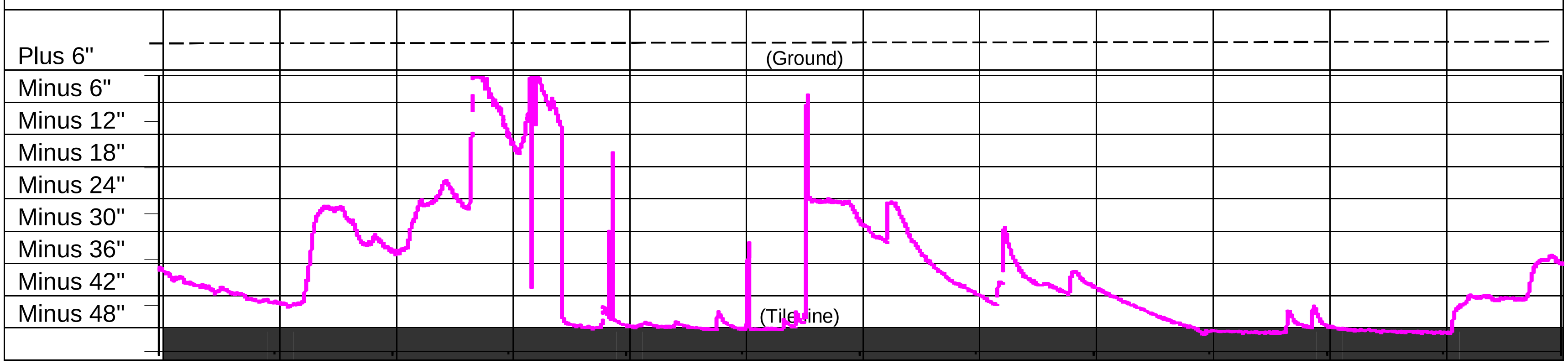
Crop:	Corn 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	4”	4”	4”	48”	48”	48”	24”	24”	24”	24”	48”	4”
2	4”	4”	4”	48”	48”	48”	24”	24”	24”	48”	48”	4”
3	4”	4”	4”	48”	48”	48”	24”	24”	24”	48”	48”	4”
4	4”	4”	4”	48”	48”	24”	24”	24”	24”	48”	48”	4”
Drain Depth												



Comments 2008 water table position

Figure 37b. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Hamilton County.

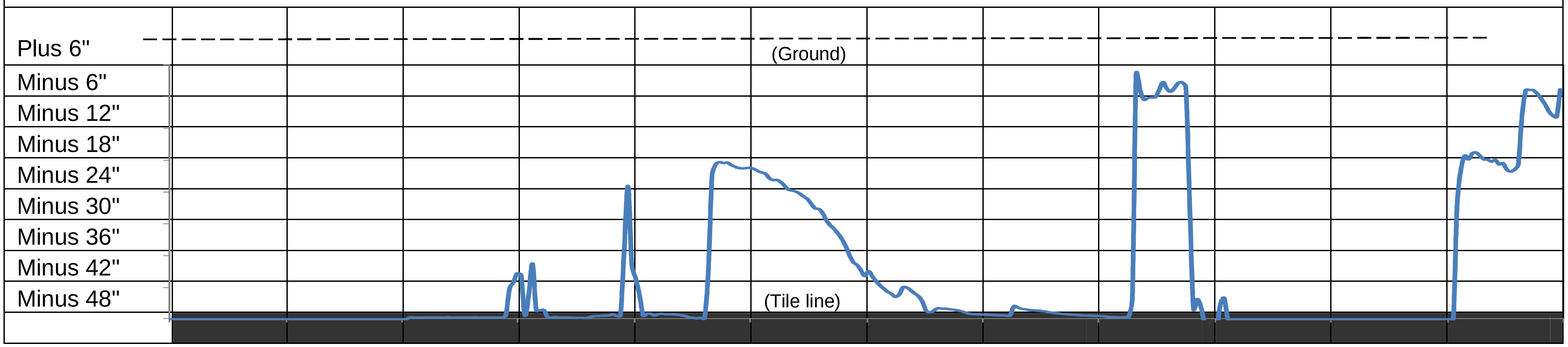
Crop:	Corn 2009											
	Jan	Feb	March	April	Ma y	June	July	August	Sept	Oct	Nov	Dec
Week												
1	4”	4”	4”	4”	48”	48”	24”	24”	24”	48”	48”	4”
2	4”	4”	4”	4”	48”	48”	24”	24”	24”	48”	48”	4”
3	4”	4”	4”	48”	48”	24”	24”	24”	24”	48”	48”	4”
4	4”	4”	4”	48”	48”	24”	24”	24”	24”	48”	48”	4”
Crop:	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	4”	4”	4”	4”	48”	48”	24”	24”	24”	48”	48”	4”
2	4”	4”	4”	4”	48”	48”	24”	24”	24”	48”	48”	4”
3	4”	4”	4”	48”	48”	24”	24”	24”	24”	48”	48”	4”
4	4”	4”	4”	48”	48”	24”	24”	24”	24”	48”	48”	4”
Drain Depth												



Comments 2009 water table position

Figure 38a. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Story City.

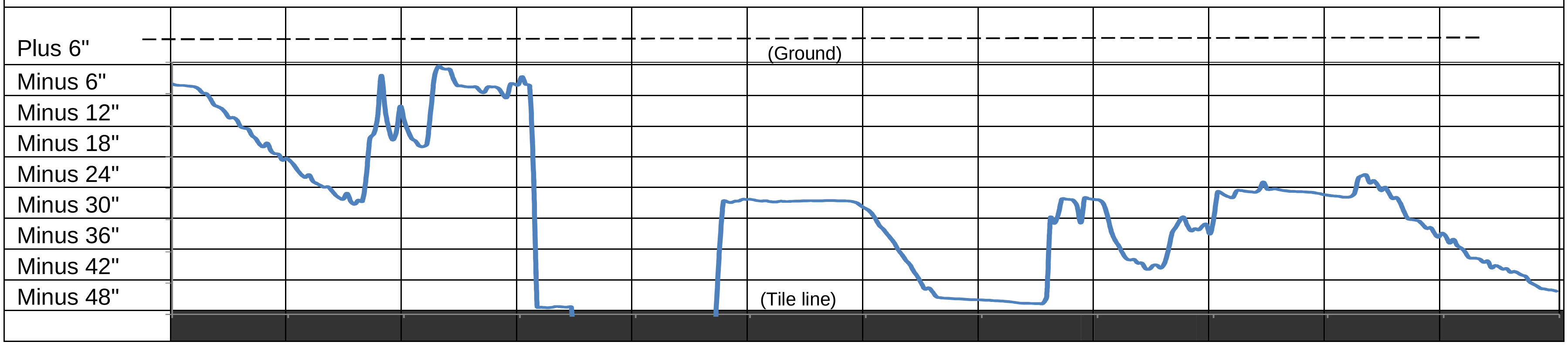
Crop:	Corn 2006											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***48"***	***48"***	***48"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***4"***	***4"***
2	***48"***	***48"***	***48"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***	***4"***
3	***48"***	***48"***	***48"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***	***4"***
4	***48"***	***48"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***4"***	***4"***	***4"***
Drain Depth												



Comments Average water level

Figure 38b. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Story City.

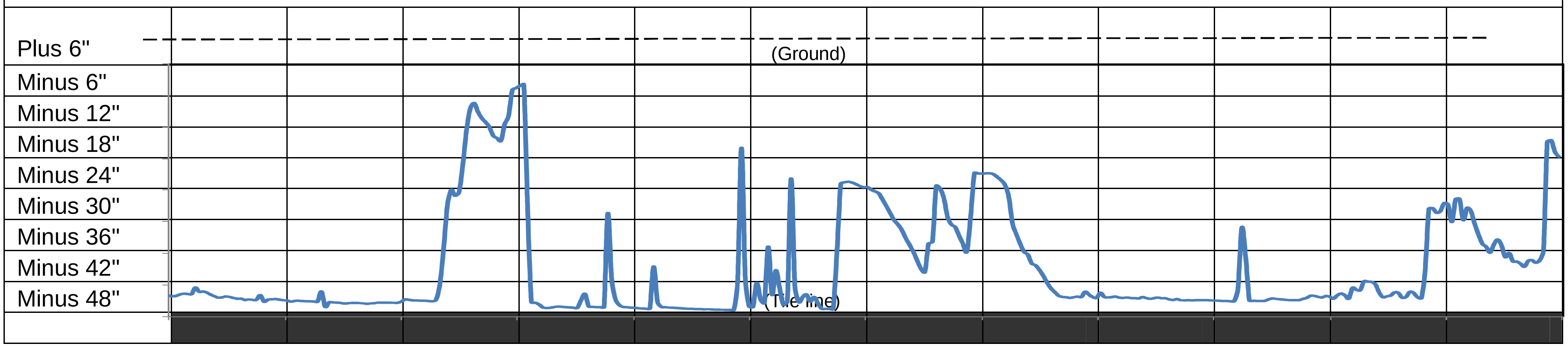
Crop:	Soybeans 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***4"***	***4"***	***4"***	***4"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***	***4"***
2	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***
3	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***
4	***4"***	***4"***	***4"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***
Drain Depth												



Comments Average water level

Figure 38c. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Story City.

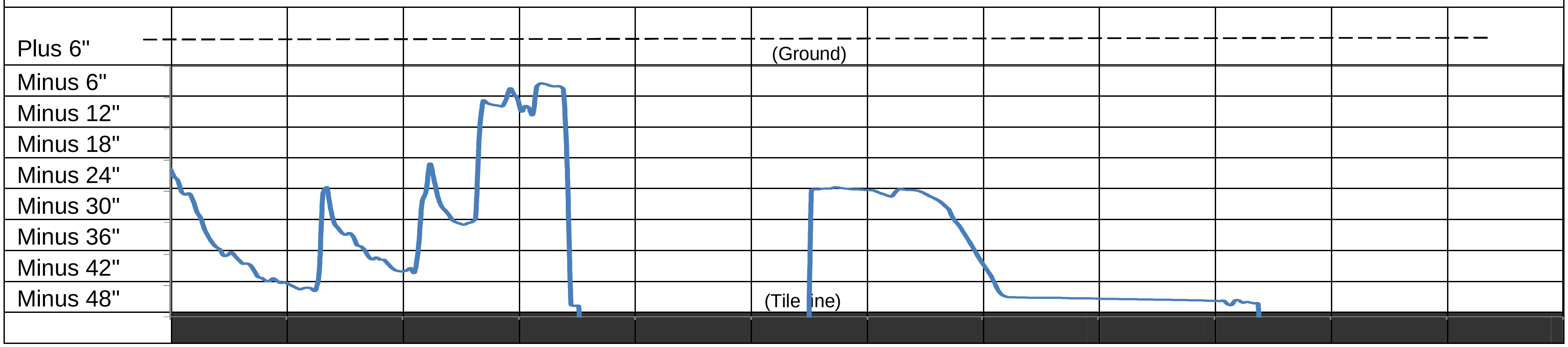
Crop:	Corn 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***4"***	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***
2	***4"***	***4"***	***4"***	***48"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***
3	***4"***	***4"***	***4"***	***48"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***4"***	***4"***
4	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***4"***	***4"***	***4"***
Drain Depth												



Comments — Average water level

Figure 38d. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Story City.

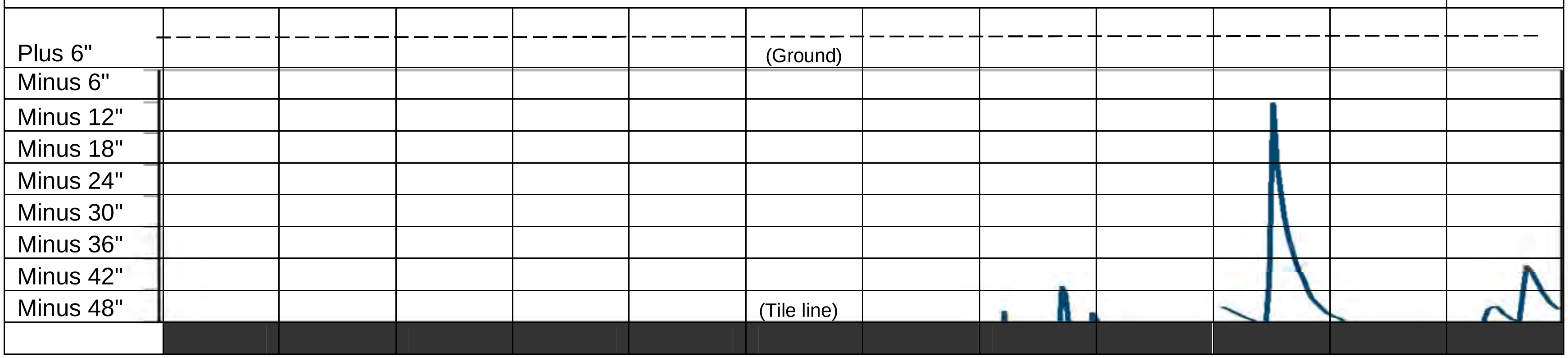
Crop:	Soybeans 2009											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***4"***	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***
2	***4"***	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***
3	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***
4	***4"***	***4"***	***4"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***	***24"***
Drain Depth												



Comments

Figure 39a. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Crawfordsville.

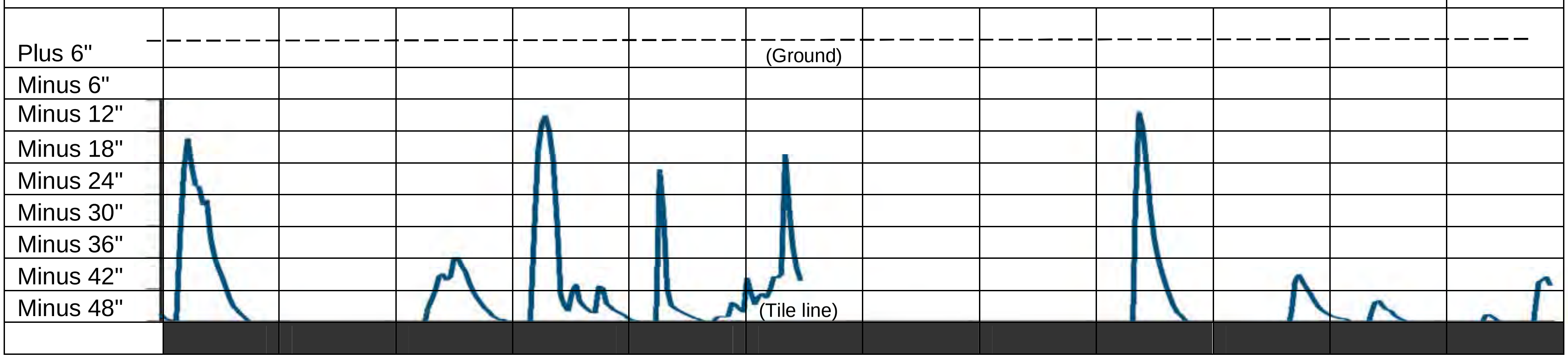
Crop:	Corn/Soybean 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
2	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
3	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
4	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
Drain Depth												



Comments Water level data were collected starting from mid-July 2007

Figure 39b. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Crawfordsville.

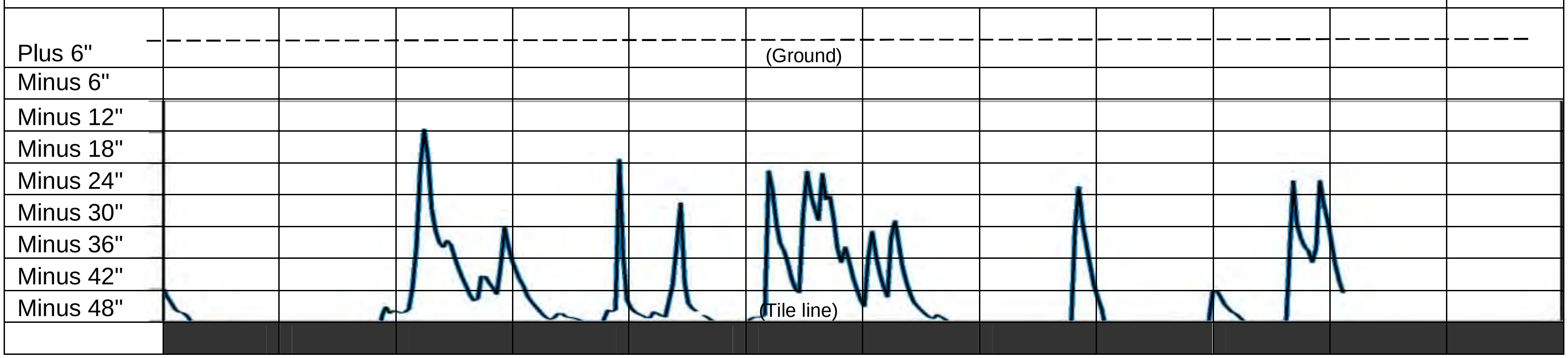
Crop:	Corn/soybean 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12”***	***12”***	***12”***	***12”***	***48"***	***48"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
2	***12”***	***12”***	***12”***	***12”***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
3	***12”***	***12”***	***12”***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
4	***12”***	***12”***	***12”***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
Drain Depth												



Comments Average water level

Figure 39c. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Crawfordsville.

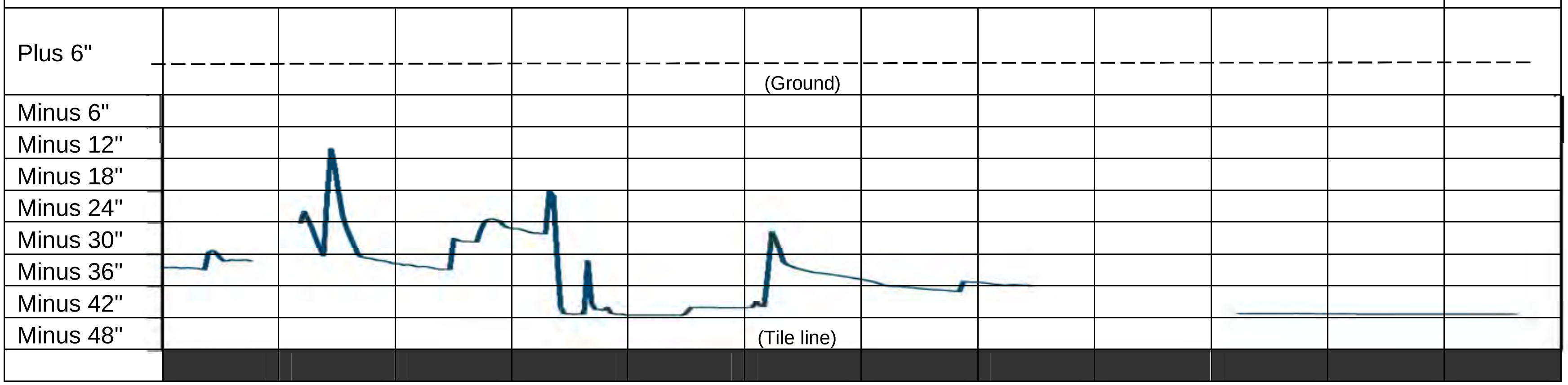
Crop:	Corn/soybean 2009											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12”***	***12”***	***12”***	***12”***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
2	***12”***	***12”***	***12”***	***12”***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
3	***12”***	***12”***	***12”***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
4	***12”***	***12”***	***12”***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***12”***	***12”***
Drain Depth												



Comments Average water level

Figure 40a. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Pekin.

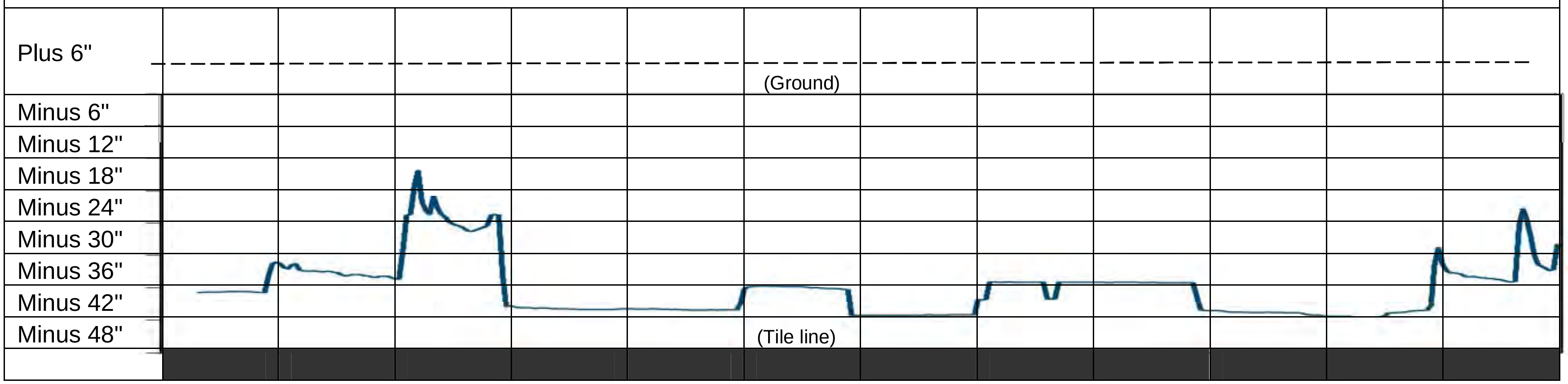
Crop:	Corn 2005											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***
2	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***
3	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
4	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
Drain Depth												



Comments Average water level

Figure 40b. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Pekin.

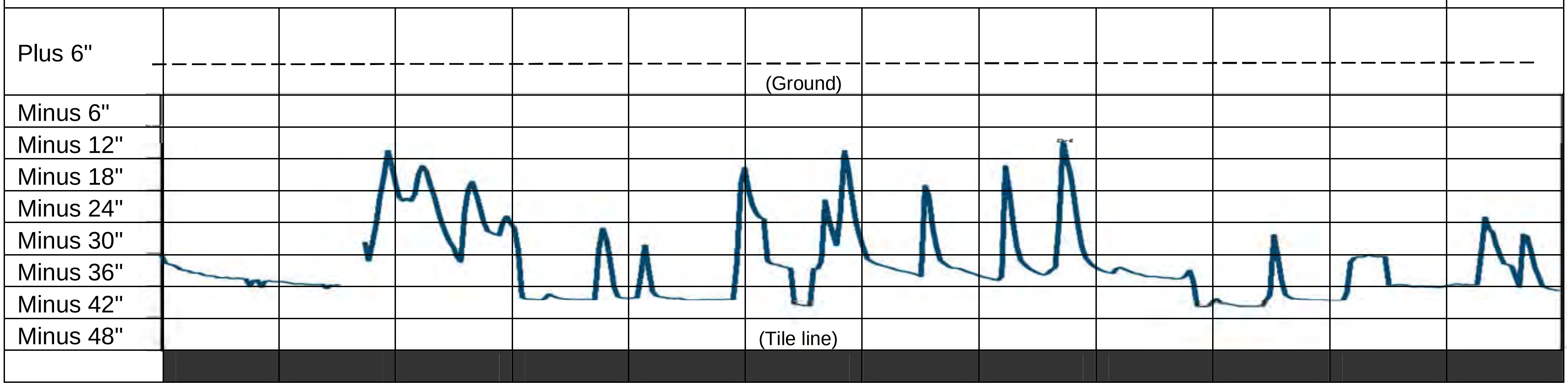
Crop:	Corn/soybean 2006											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***
2	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***
3	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***
4	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
Drain Depth												



Comments Average water level

Figure 40c. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Pekin.

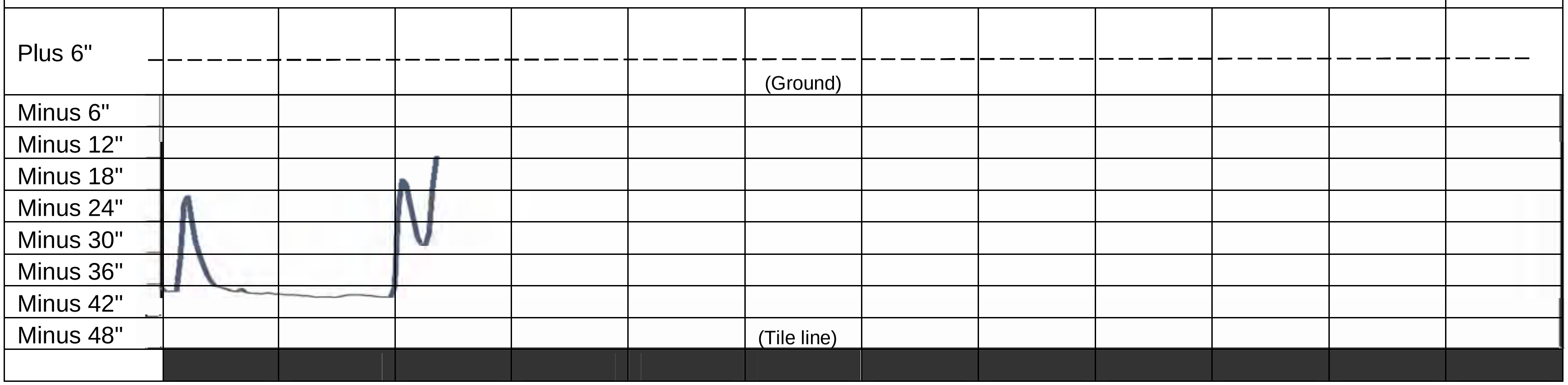
Crop:	Corn/soybean 2007											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***
2	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***
3	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***
4	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
Drain Depth												



Comments Average water level

Figure 40d. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Pekin.

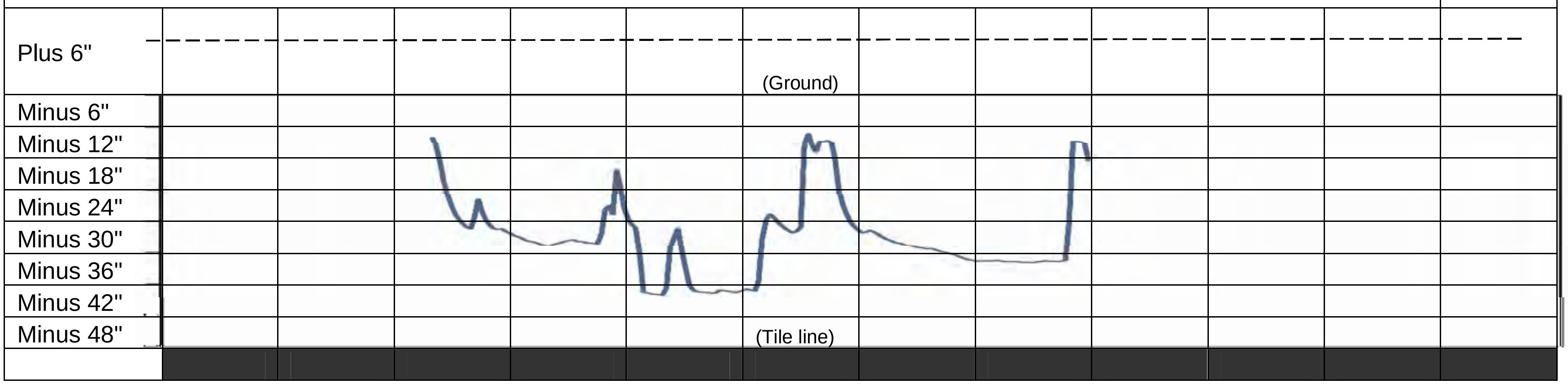
Crop:	Corn/soybean 2008											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***
2	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***
3	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
4	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***24"***	***24"***
Drain Depth												



Comments Average water level; no data available after mid-March

Figure 40e. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Pekin.

Crop:	Corn/soybean 2009											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***24"***	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***48"***
2	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***	***24"***	***24"***	***48"***	***48"***	***48"***
3	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***48"***	***24"***
4	***24"***	***24"***	***24"***	***24"***	***48"***	***24"***	***24"***	***24"***	***48"***	***48"***	***48"***	***24"***
Drain Depth												



Comments Average water level

Iowa Cropping and Yield Data

Table 4a. Cropping and yield data for Site 1 (Hamilton County, Iowa).

		2006		2007		2008		2009	
Crop				Corn		Corn		Corn	
Variety				Agrigold 6395		Wyffels 5281VT3			
Planting Date				5/12		5/15			
Row Spacing				30”		30”			
Tillage	**Conventional**			Fall disked		Fall disked			
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre			17					
Pre-plant N application	**Date**			5/11		5/14			
	Actual N#s/acre			180		180			
Post-plant N application	**Date**								
	Actual N#s/acre								
Phosphorus	**Actual P#s/acre**			78		0			
Potash	**Actual K#s/acre**			94		62.5			
Herbicide	**oz/acre**			glyphosate		Volley/glyphosate			
Insecticide	**oz/acre**								
Harvest date				Nov 15		Nov 5			
Drainage	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield				194.1	197.7	124.3	139.3		
Moisture				14.3	15.3	19.2	19.6		
Comments (hail, drought, heat, wind, etc.)									

Table 4b. Cropping and yield data for Site 2 (Story City, Iowa).

		2006		2007		2008		2009	
Crop		Corn		Soybean		Corn		Soybean	
Variety						Dekalb 6199			
Planting Date		4/13		5/9		5/3		5/20	
Row Spacing		30”		7.5“		30”		7.5”	
Tillage	**Conventional**	*		*		*		*	
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**								
	Actual N#s/acre								
Post-plant N application	**Date**	5/22				5/21			
	Actual N#s/acre	120				140			
Phosphorus	**Actual P#s/acre**								
Potash	**Actual K#s/acre**								
Herbicide	**oz/acre**			glyphosate				glyphosate	
Insecticide	**oz/acre**								
Harvest date		Oct 3		Sept 27		Oct 9		Oct 13	
Drainage	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield		173.9	167.4	64.0	57.8	207.7	211.1	60.1	57.7
Moisture		16.8	16.6	12.1	12.1	21.2	21.4	13.5	13.5
Comments (hail, drought, heat, wind, etc.)	**Yield (corrected to 15.5% moisture for corn and 13% for soybean)**								

Table 4c. Cropping and yield data for Site 3 (Crawfordsville, Iowa).

		2007*			2008			2009		
Crop		corn/soybean			corn/soybean			corn/soybean		
Variety					Mycogen 2D675, Pioneer 93M42			Pioneer 34Y03, Pioneer 93M11		
Planting Date					5/9, 6/2			4/17-18, 5/22		
Row Spacing					30"/7.5"			30"/7.5"		
Tillage	**Conventional**				Fall chiseled corn stalks					
	Conservation							*		
	No Till									
Nitrogen										
Fall N application	**Date**									
	Actual N#s/acre				280# DAP			280# DAP		
Pre-plant N application	**Date**				5/4			4/11		
	Actual N#s/acre				75			125		
Post-plant N application	**Date**									
	Actual N#s/acre									
Phosphorus	**Actual P#s/acre**									
Potash	**Actual K#s/acre**				200# 0-0-60			200# 0-0-60		
Herbicide	**oz/acre**				glyphosate			glyphosate		
Insecticide	**oz/acre**									
Harvest date					Oct 11, Nov 3-5			Oct 7, 12-13, 19-20		
Drainage	MD-Managed drainage, SD-Shallow drainage, CD-conventional drainage	**MD**	**SD**	**CD**	**MD**	**SD**	**CD**	**MD**	**SD**	**CD**
Corn Yield	Bu/ac	170.6	177.3	178.5	168.2	175.7	171.6	152.5	161.9	169.9
Moisture	%	17.9	17.6	18.0	18.1	17.8	17.8	19.2	18.8	19.3
Soybean Yield	Bu/ac	55.9	51.4	57.8	47.6	45.2	46.9	63.4	62.6	67.4
Moisture	%	11.5	11.3	11.4	12.0	11.7	12.0	14.2	14.2	14.1
Comments (hail, drought, heat, wind, etc.)	* Site managed by local farmer; no records of variety and fertilizer available at this time.									

Table 4d. Cropping and yield data for Site 4 (Pekin, Iowa)*.

		2007			2008			2009**		
Crop		Corn/soybean			Corn/soybean			Corn/soybean		
Variety										
Planting Date										
Row Spacing		30”/7.5”			30”/7.5”			30”/7.5”		
Tillage	**Conventional**									
	Conservation									
	No Till									
Nitrogen										
Fall N application	**Date**									
	Actual N#s/acre									
Pre-plant N application	**Date**									
	Actual N#s/acre									
Post-plant N application	**Date**									
	Actual N#s/acre									
Phosphorus	**Actual P#s/acre**									
Potash	**Actual K#s/acre**									
Herbicide	**oz/acre**									
Insecticide	**oz/acre**									
Harvest date										
Drainage	MD-Managed drainage, SD-Shallow drainage***, CD-conventional drainage	**MD**	**SD**	**CD**	**MD**	**SD**	**CD**	**MD**	**SD**	**CD**
Corn Yield	**Bu/ac**	141.7	127.7	139.3	223.4	218.6	228.1			
Moisture	**%**	15.6	15.6	15.6	16.9	16.5	16.7			
Soybean Yield	**Bu/ac**	45.7	45.3	43.7	44.0	44.4	41.8	55.3	53.6	57.7
Moisture	**%**	10.1	10.0	10.0	9.7	9.7	9.5	10.4	10.6	10.0
Comments (hail, drought, heat, wind, etc.)										

*Still trying to get specific management from FFA Chapter;

** No corn yield data for individual plots but the average corn yield was estimated to be 148 bu/acre;

*** Pseudo-shallow drainage: control structure set at 2 ft below surface year-round.

Ohio Site Descriptions

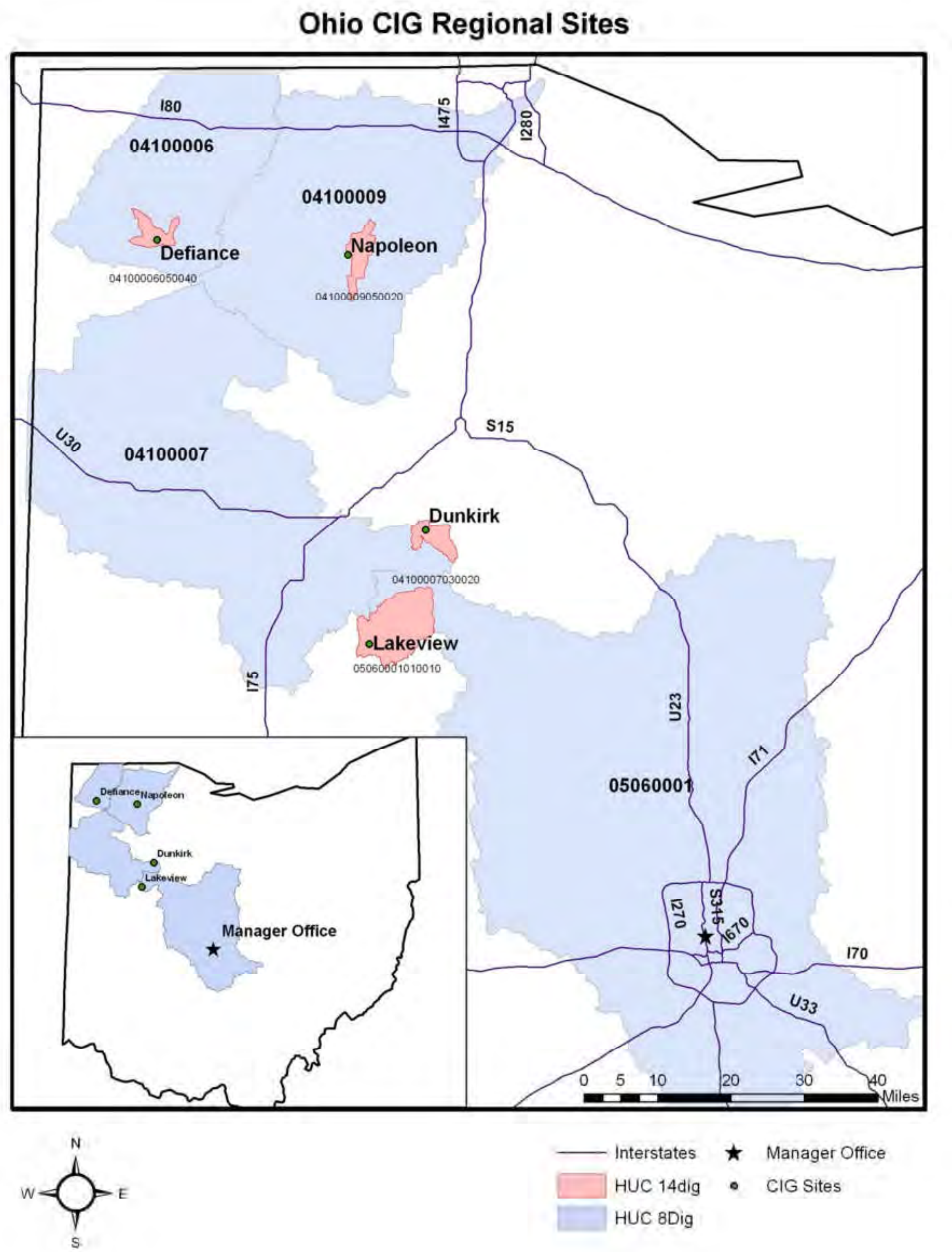


Table 5. Ohio site descriptions

Sites	Site 1	Site 2	Site 3	Site 4
Site Name	**Defiance**	**Napoleon**	**Dunkirk**	**Lakeview**
Managed drainage (ac)	20	38	16	20
Conventional drainage (ac)	19	35	13	30
Dominant soil types	Paulding clay; Roselms silty clay	Mermill loam, clay loam	Blount silt loam; Pewamo silty clay loam; Mf	Mermill clay loam
Watershed name	Tiffin River	Lower Maumee River	Auglaize River	Upper Scioto River
14-Digit HUC	4100006050040	4100009050020	4100007030020	5060001010010
30-year precipitation average, in (record)	35.2 (1971-2000)	34.7 (1961-1990)	35.2 (1971-2000)	38.7 (1971-2000)
Subsurface drainage system installation year	2004 w/wtcs retrofit in 2001	Existing clay tile, updated in 2005 w/wtcs retrofit in 2007	2006-2007 w/wtcs retrofit in 2007	1988-1989; w/wtcs retrofit in 2007
Depth of ssd pipe	2.5'-3.5'	2.5'-3.5'	2.5'-3.5'	3.0'-3.5'
Drainage coefficient	3/8"	3/8"	3/8"	3/8" or 1/2"
SSD spacing, ft	40	40' avg	20	50
New or retrofit system	Retrofit	Retrofit	New	Retrofit
Water table control structure installation year	1st one previous to 2007; 2nd one in 2007	1st one previous to 2007; 2nd one in 2007/2008	Both in 2007	Both in 2007
Laterals on the contour (Yes or No)?	No	0% slope, Yes	No	0% slope, Yes

Figure 41. Defiance site soil map.

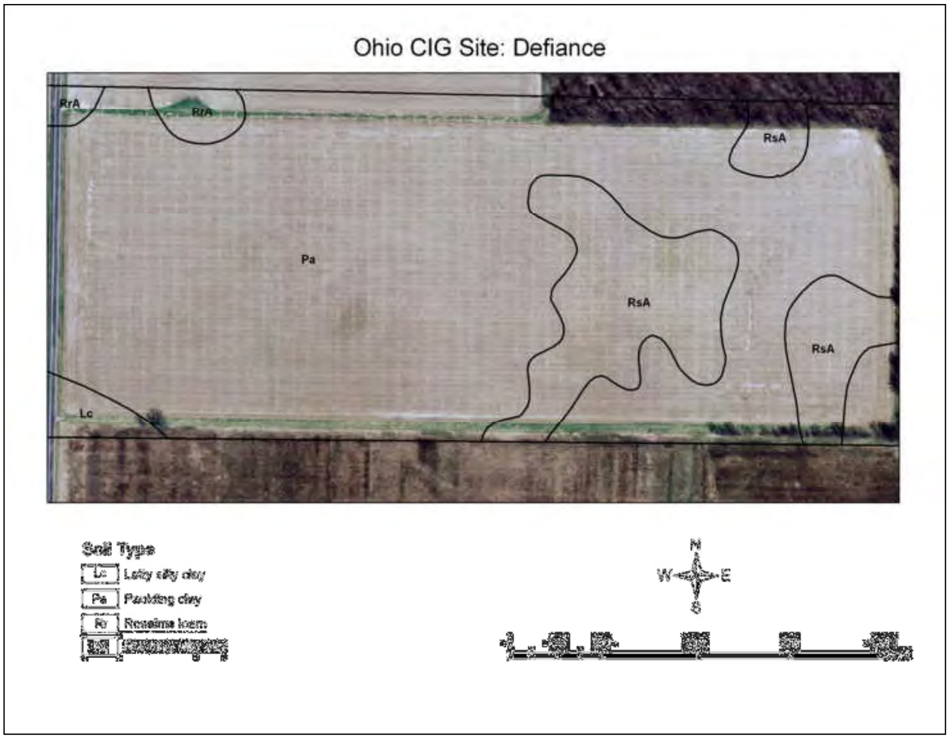


Figure 42. Defiance site tile map.

Figure 43. Defiance site topographical map.

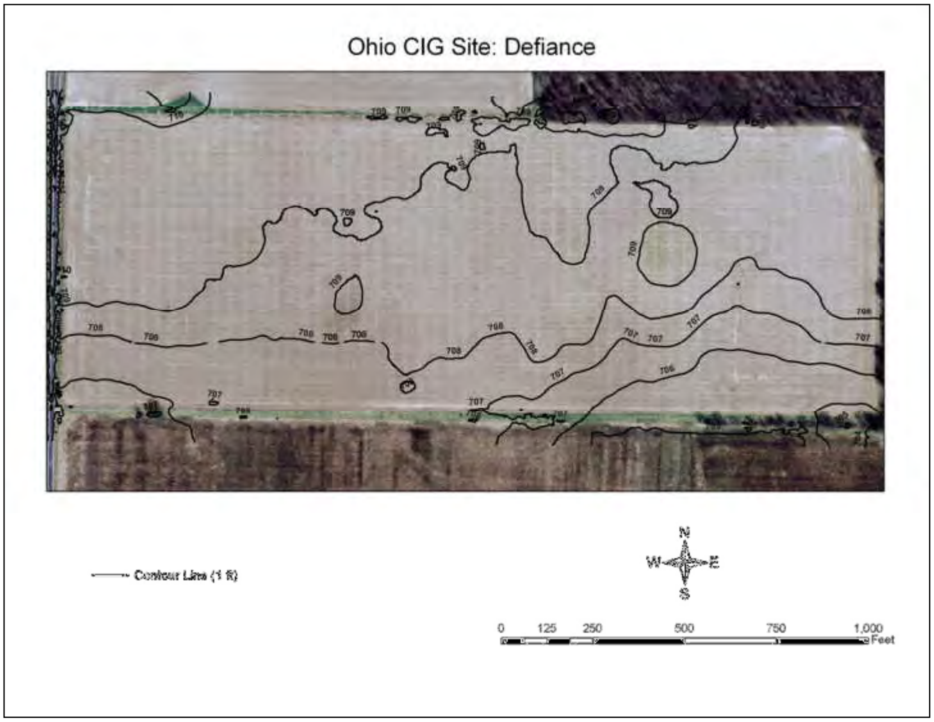


Figure 44. Defiance site aerial map.

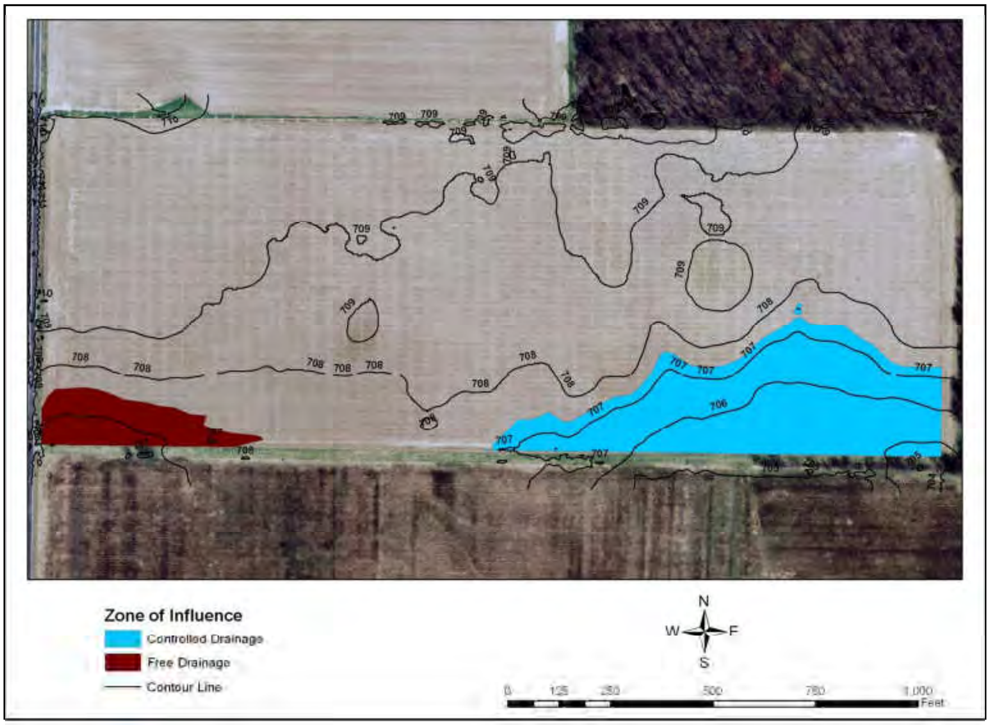


Figure 45. Napoleon site soil map.

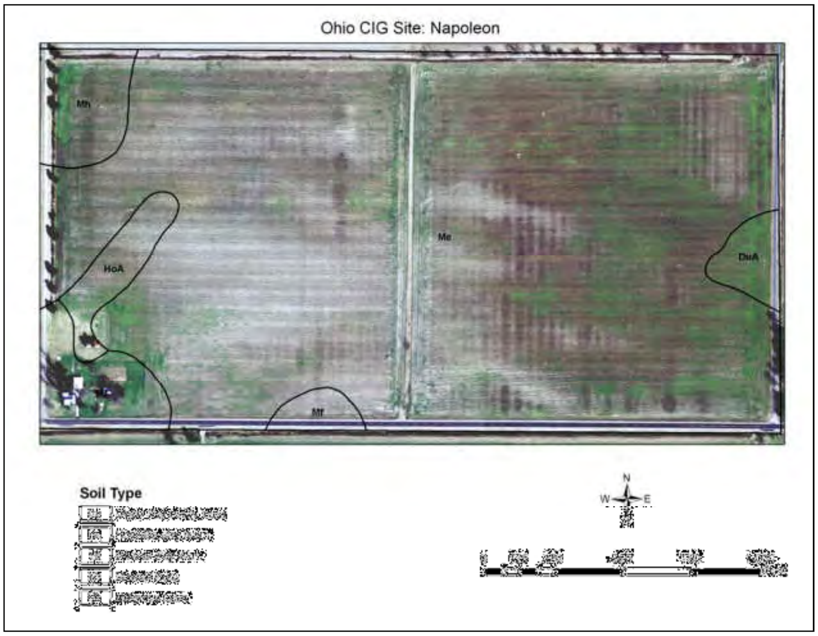


Figure 46. Napoleon site tile map.

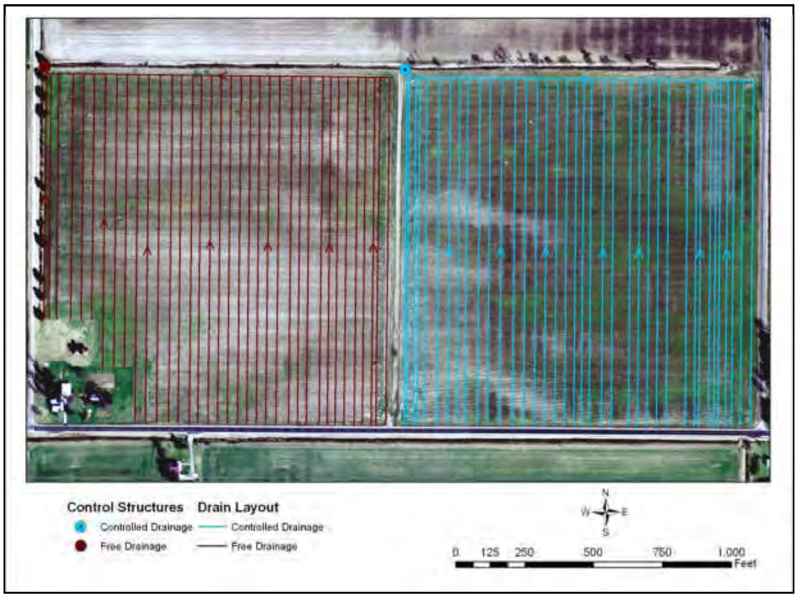


Figure 47. Napoleon site topographical map.

Figure 48. Napoleon site aerial map.

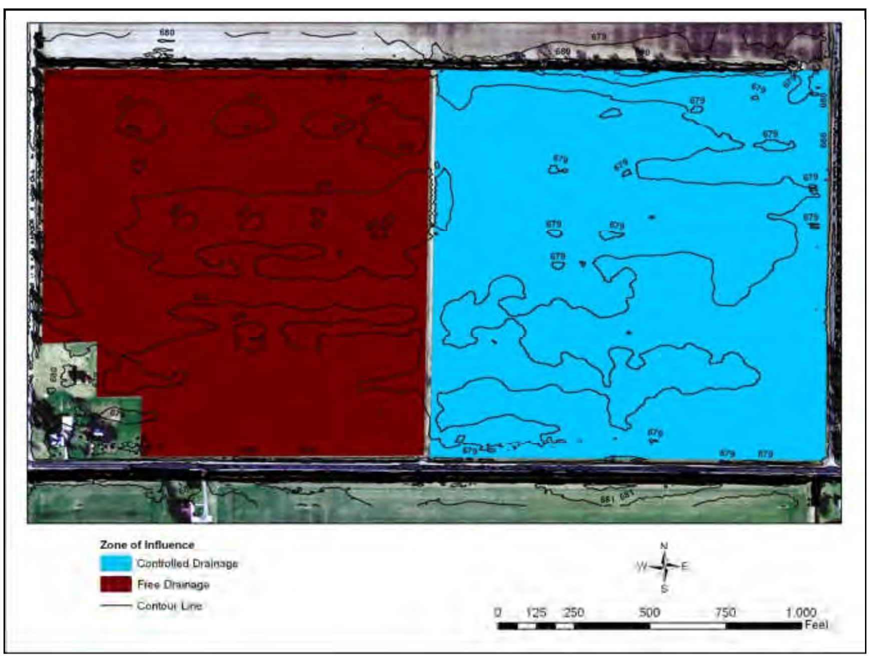


Figure 49. Dunkirk site soil map.

Figure 50. Dunkirk site tile map.

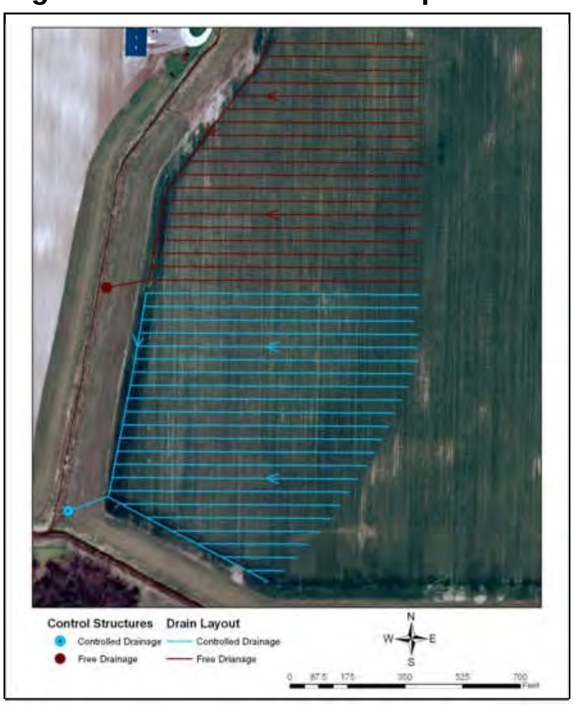


Figure 51. Dunkirk site topographical map.

Figure 52. Dunkirk site aerial map.

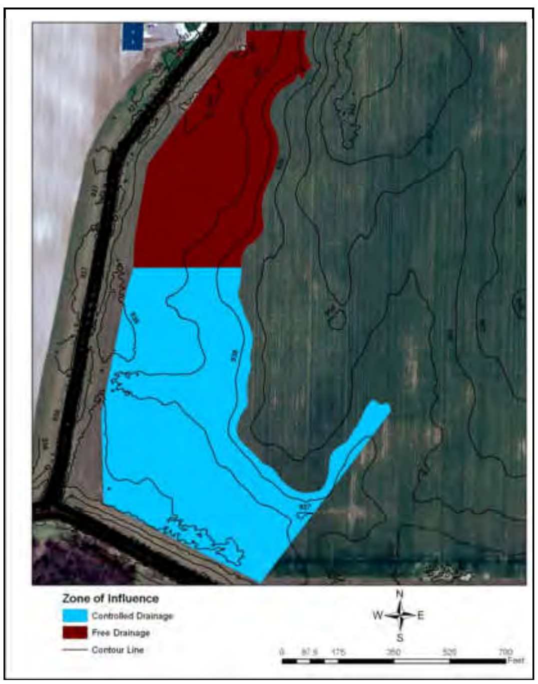


Figure 53. Lakeview site soil map.

Figure 54. Lakeview site tile map.

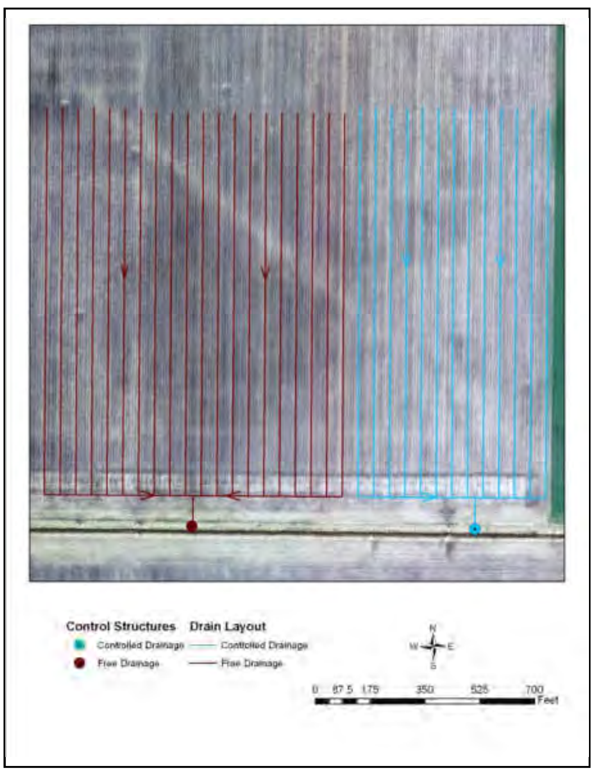
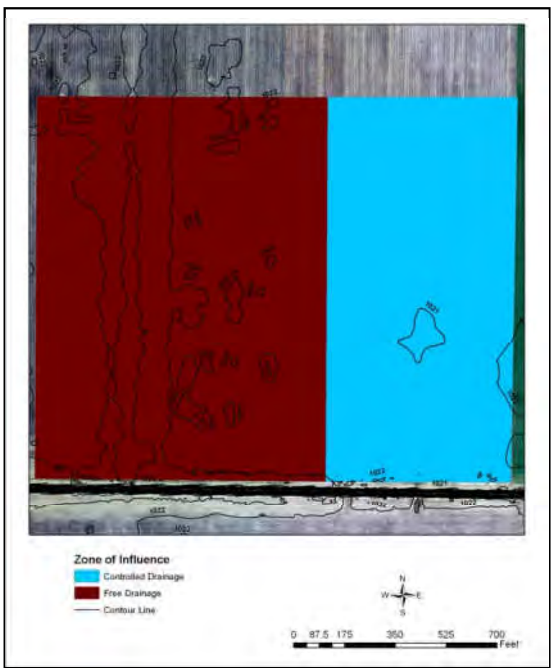


Figure 55. Lakeview site topographical map.

Figure 56. Lakeview site aerial map.



Ohio Water Management Plan

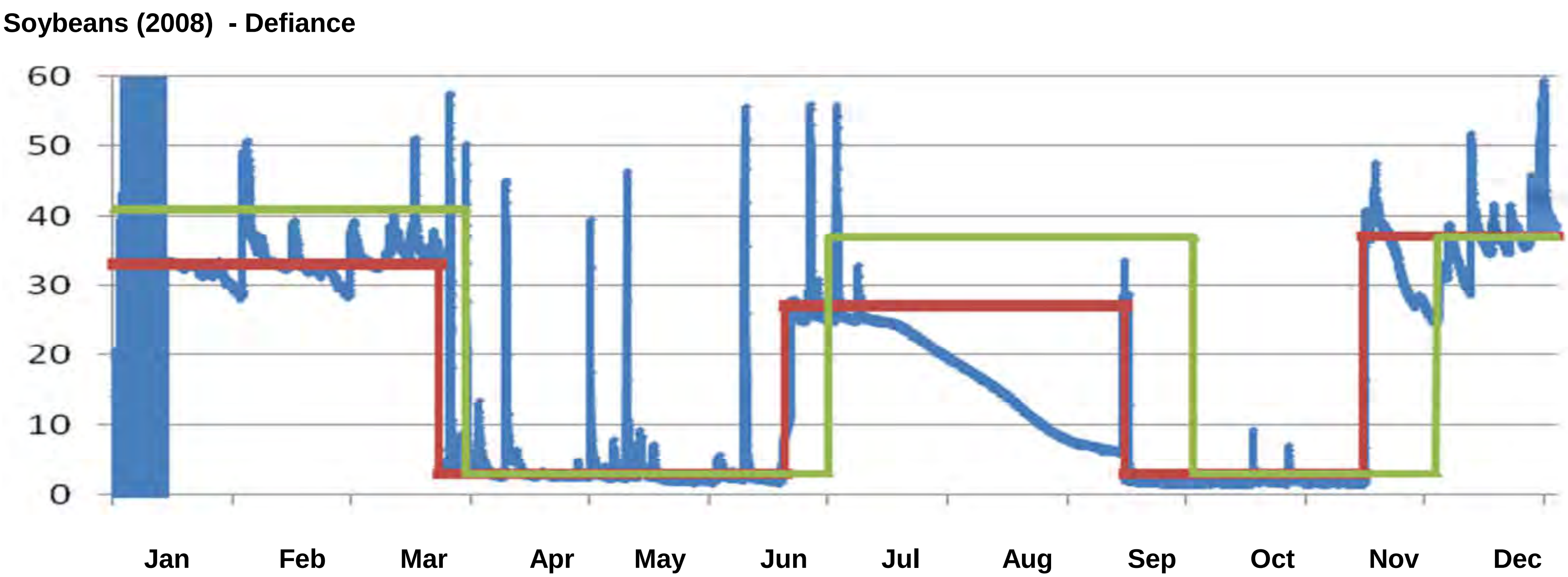
Figure 57. Recommended Water Control Plan for DWM at Ohio Sites.

site	Defiance From bottom of WTCs, Depth = 41”=7”+7”+5”+7”+5”+7”+Vboard (Vboard = 3"); Depth = 37”=5”+5”+7”+5”+7”+5”+Vboard											
week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	41”	41”	41”	3”	3”	3”	37”	37”	37”	3”	3”	37”
2	41”	41”	41”	3”	3”	3”	37”	37”	37”	3”	3”	37”
3	41”	41”	41”	3”	3”	3”	37”	37”	37”	3”	3”	37”
4	41”	41”	41”	3”	3”	3”	37”	37”	37”	3”	3”	37”
site	Dunkirk, Napoleon, Lakeview From bottom of WTCs, Depth = 37”=5”+7”+5”+7”+5”+Vboard (V-board = 8"); Depth = 13”=5”+Vboard											
week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	37”	37”	37”	13”	13”	13”	37”	37”	37”	13”	13”	37”
2	37”	37”	37”	13”	13”	13”	37”	37”	37”	13”	13”	37”
3	37”	37”	37”	13”	13”	13”	37”	37”	37”	13”	13”	37”
4	37”	37”	37”	13”	13”	13”	37”	37”	37”	13”	13”	37”

Comments: At Defiance, the top board is a 7” V-notch board, with a 4” V-notch cut, depth of the top board is 3” to the v-point. At Dunkirk, Napoleon, and Lakeview, the top board is a 12” V-notch board, with a 4” V-notch cut, depth of the top board is 8” to the V-point. In the following graphs, data were plotted only when water levels were available from both structures at a site.

Figure 58a. Actual Control Plan and Water Table for DWM in 2008 (depth from bottom of structure in inches) – Defiance
Note: Top board is a 7" V-notch board, with a 4" V-notch cut, depth of the top board is 3" to the V-point.

Actual setting	Soybeans (2008) 34"= 7"+5"+7"+5"+7"+Vboard 3"=Vboard 37"=5"+5"+7"+5"+7"+5"+Vboard 27"=7"+5"+7"+5"+Vboard										
Week	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	34"	34"	34"	3"	3"	3"	27"	27"	27"	3"	3"	37"
2	34"	34"	34"	3"	3"	3"	27"	27"	27"	3"	3"	37"
3	34"	34"	34"	3"	3"	3"	27"	27"	3"	3"	37"	37"
4	34"	34"	3"	3"	3"	27"	27"	27"	3"	3"	37"	37"

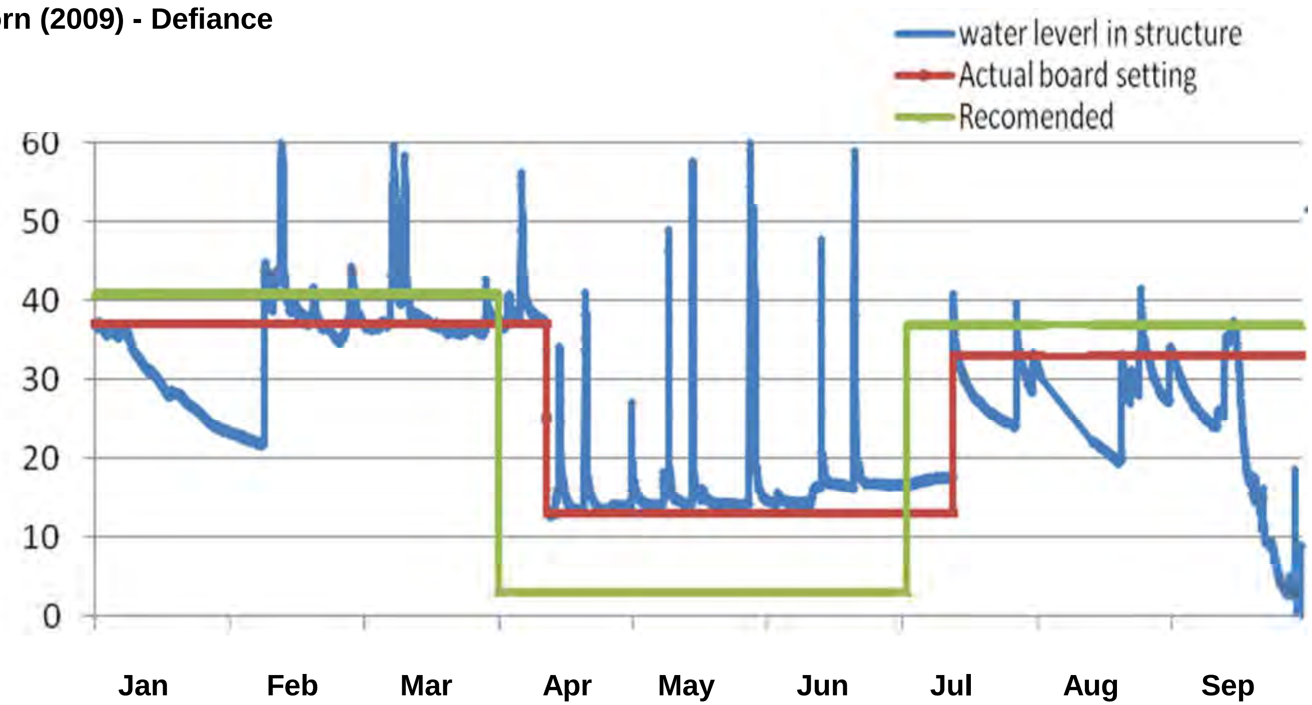


Comments: The water depth at the beginning of January, up to Jan 16th in 2008 was not considered reasonable, possibly because of instrument failure. Also, some single discrete readings (negative or readings more than 60 inches) were deleted.

Figure 58b. Actual Control Plan and Water Table for DWM in 2009 (depth from bottom of structure in inches) – Defiance. Note: Top board is a 7" V-notch board, with a 4" V-notch cut, depth of the top board is 3" to the V-point.

Actual setting	Corn (2009)			37"=5"+5"+7"+5"+7"+5"+Vboard			13"=5"+5"+Vboard					
Week	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	37"	37"	37"	37"	13"	13"	13"	13"	13"	13"	13"	13"
2	37"	37"	37"	13"	13"	13"	13"	13"	13"	13"	13"	13"
3	37"	37"	37"	13"	13"	13"	13"	13"	13"	13"	13"	13"
4	37"	37"	37"	13"	13"	13"	13"	13"	13"	13"	13"	13"

Corn (2009) - Defiance



Comments: The readings of water table after September were not used due to instrument failure.

Figure 59a. Actual Control Plan and Water Table for DWM in 2008 (depth from bottom of structure in inches) – Napoleon. Note: top board is a 12" V board, with a depth of 4" V cut and the depth of the top board is 8" to the V-point.

Actual Setting	Popcorn (2008)										
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	44"	44"	44"	32"	32"	32"	37"	37"	37"	8"	8"	8"
2	44"	44"	44"	32"	32"	32"	37"	37"	37"	8"	8"	8"
3	44"	44"	44"	32"	32"	32"	37"	37"	37"	8"	8"	8"
4	44"	44"	32"	32"	32"	37"	37"	37"	37"	8"	8"	8"

Popcorn (2008) - Napoleon

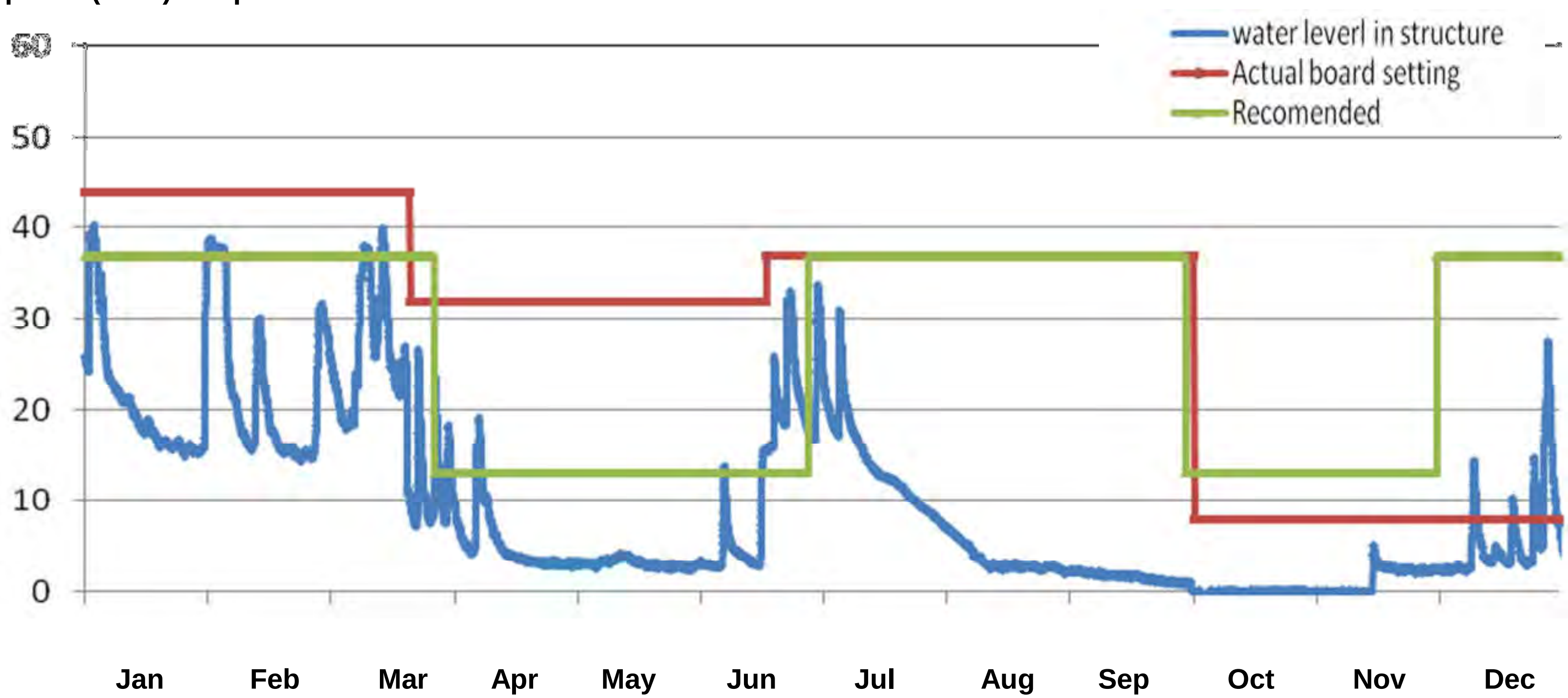
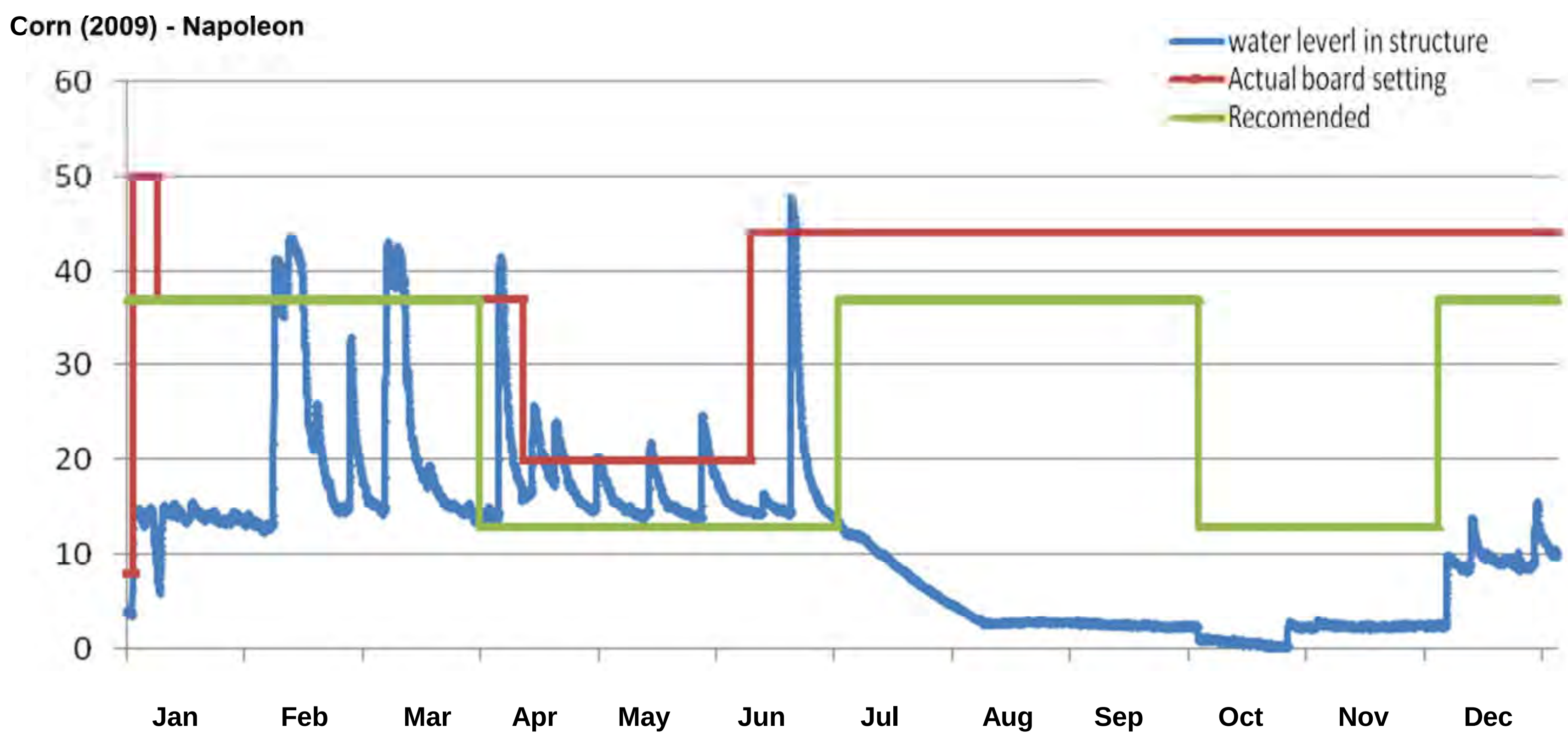


Figure 59b. Actual Control Plan and Water Table for DWM in 2009 (depth from bottom of structure in inches) – Napoleon. Note: top board is a 12" V board, with a depth of 4" V cut and the depth of the top board is 8" to the V-point.

Actual Setting	Corn (2009)										
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	50"	37"	37"	37"	20"	20"	44"	44"	44"	44"	44"	44"
2	37"	37"	37"	20"	20"	44"	44"	44"	44"	44"	44"	44"
3	37"	37"	37"	20"	20"	44"	44"	44"	44"	44"	44"	44"
4	37"	37"	37"	20"	20"	44"	44"	44"	44"	44"	44"	44"

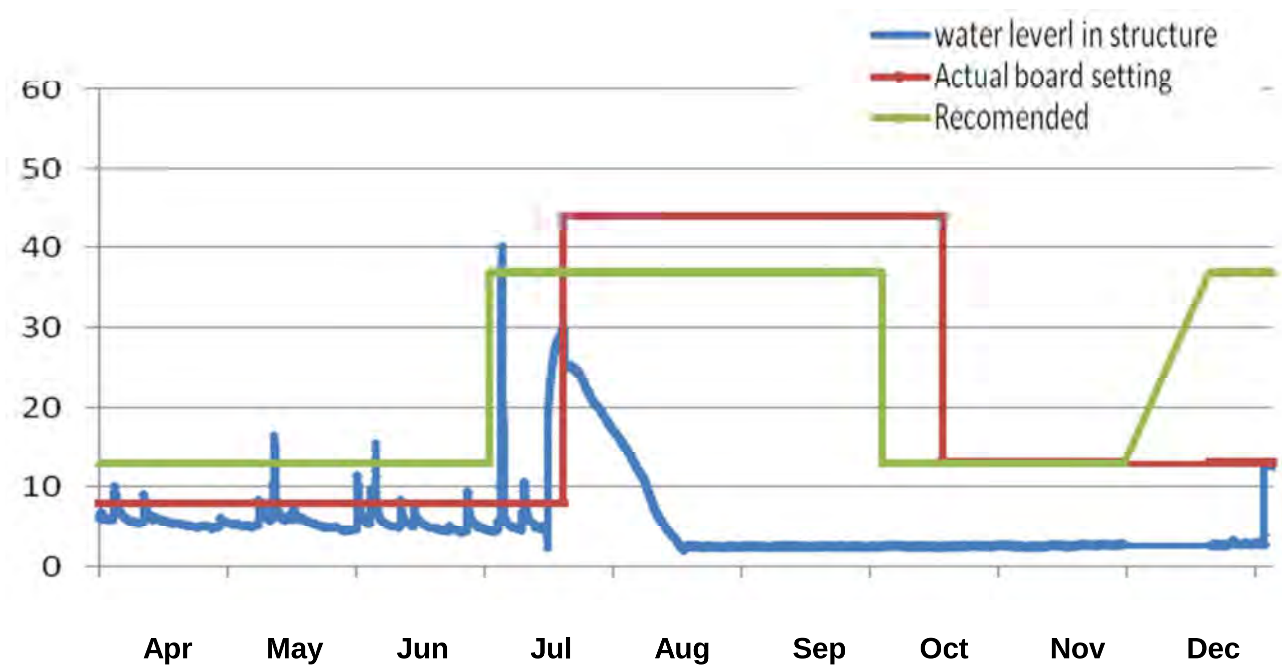


Comments: The actual board setting at the beginning of January may be wrong due to incomplete field records.

Figure 60a. Actual Control Plan and Water Table for DWM in 2008 (depth from bottom of structure in inches) – Dunkirk. Note: Top board is a 12" V-notch board, with a 4" V-notch cut, depth of the top board is 8" to the V-point.

Actual Setting	Corn (2008)											
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	36"	36"	36"	8"	8"	8"	8"	44"	44"	44"	13"	13"
2	36"	36"	36"	8"	8"	8"	8"	44"	44"	44"	13"	13"
3	36"	36"	8"	8"	8"	8"	44"	44"	44"	13"	13"	13"
4	36"	36"	8"	8"	8"	8"	44"	44"	44"	13"	13"	13"

Corn (2008) - Dunkirk



Comments: Water level before April 2008 was not available. Also, the water level from Dec 1st to Dec 26th was lost due to instrument failure. The recommended time of lifting the board is at the beginning of December.

Figure 60b. Actual Control Plan and Water Table for DWM in 2009 (depth from bottom of structure in inches) – Dunkirk. Note: Top board is a 12" V board, with a depth of 4" V cut and the depth of the top board is 8" to the V-point.

Actual Setting	Soybeans (2009)											
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	36"	36"	36"	36"	20"	20"	46"	46"	46"	46"	46"	46"
2	36"	36"	36"	36"	20"	34"	46"	46"	46"	46"	46"	46"
3	36"	36"	36"	20"	20"	34"	46"	46"	46"	46"	46"	46"
4	36"	36"	36"	20"	20"	34"	46"	46"	46"	46"	46"	46"

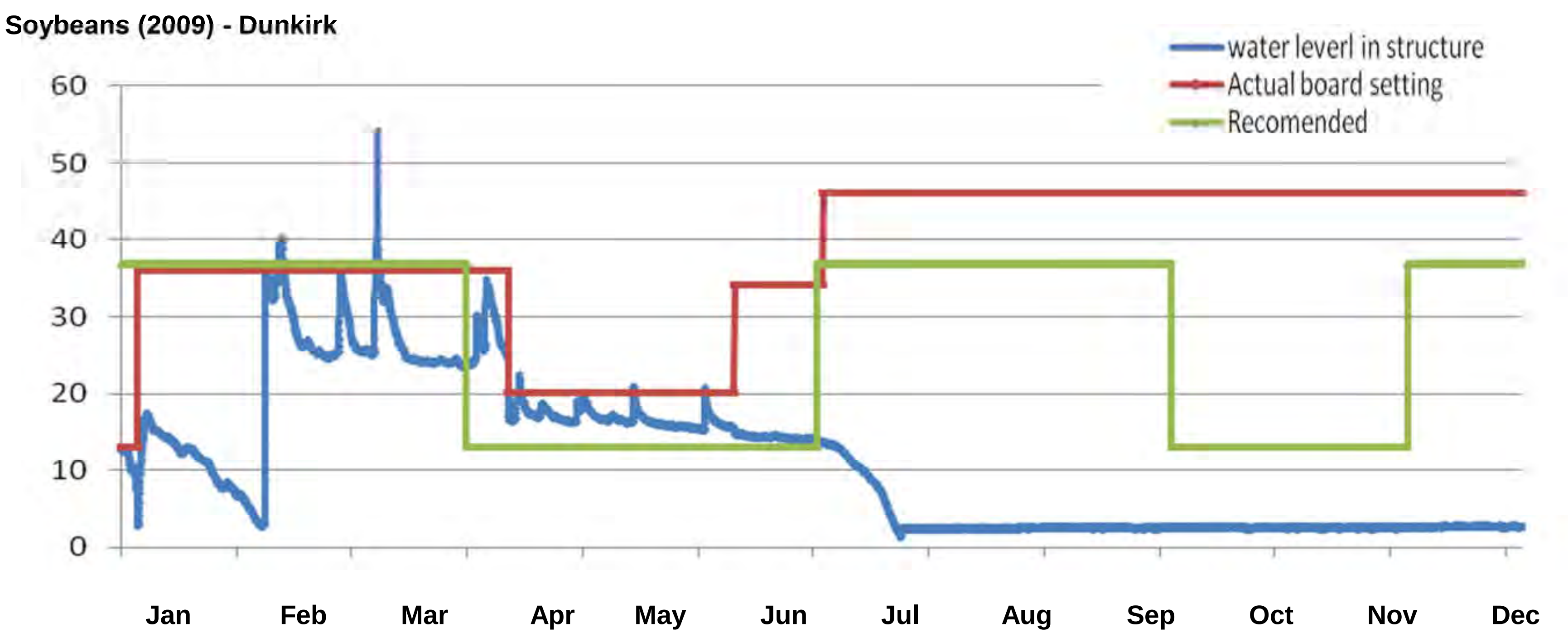


Figure 61a. Actual Control Plan and Water Table for DWM in 2008 (depth from bottom of structure in inches) – Lakeview. Note: top board is a 12" V board, with a depth of 4" V cut and the depth of the top board is 8" to the V-point.

Actua Setting	Soybeans (2008)											
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	39"	39"	39"	13"	13"	13"	37"	37"	37"	13"	13"	13"
2	39"	39"	39"	13"	13"	13"	37"	37"	37"	13"	13"	13"
3	39"	39"	39"	13"	13"	37"	37"	37"	37"	13"	13"	13"
4	39"	39"	13"	13"	13"	37"	37"	37"	37"	13"	13"	13"

Soybeans (2008) - Lakeview

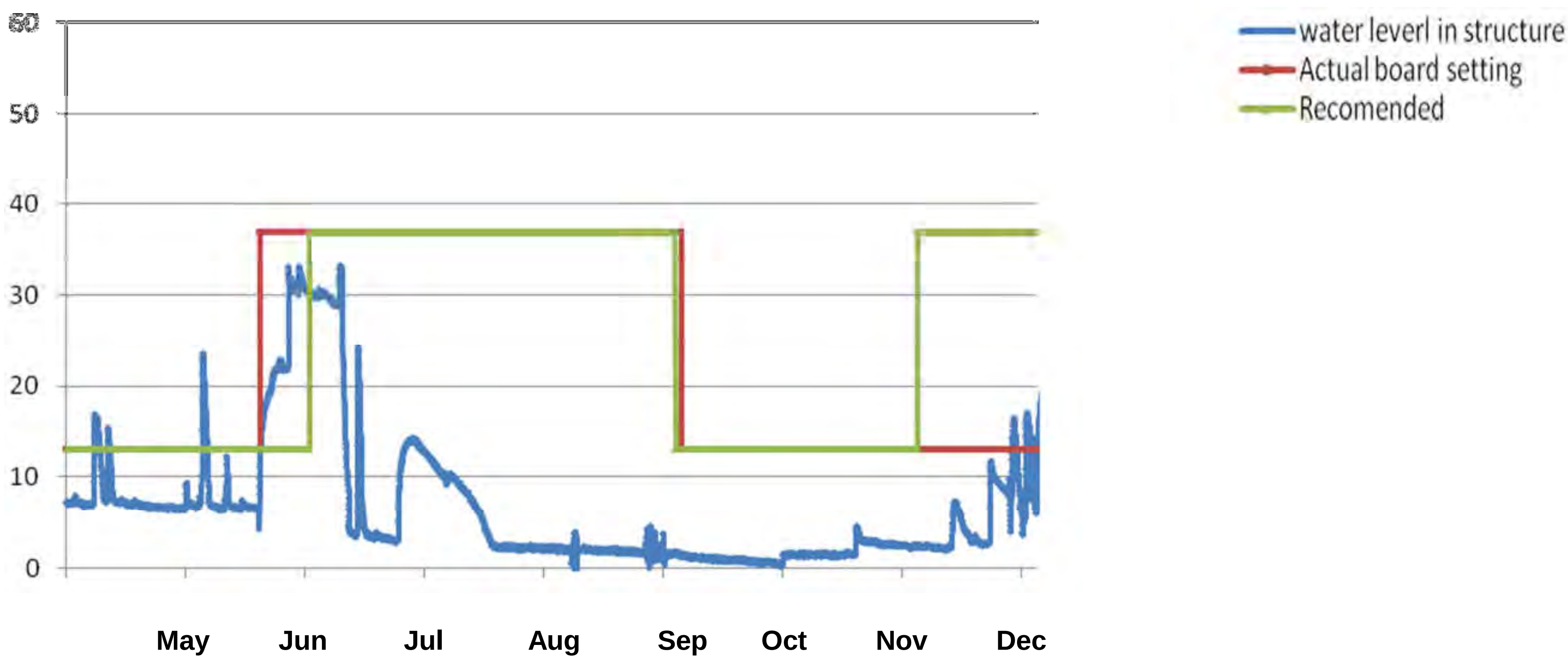
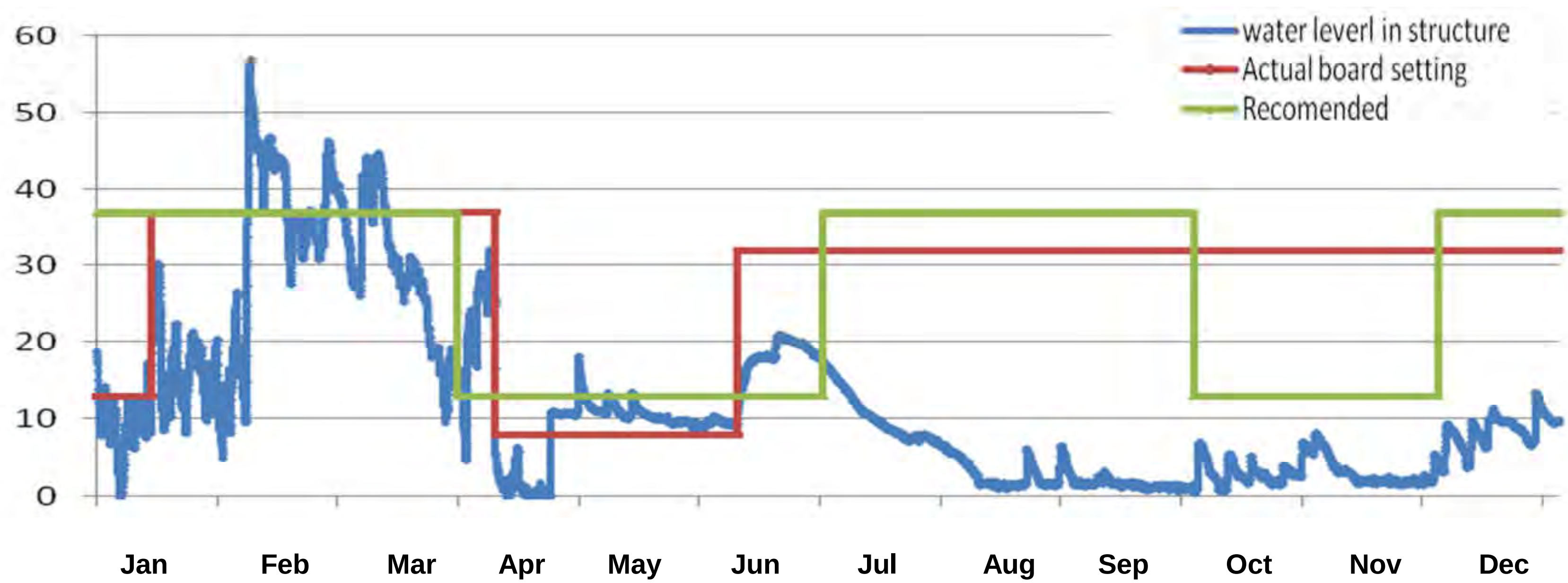


Figure 61b. Actual Control Plan and Water Table for DWM in 2009 (depth from bottom of structure in inches) – Lakeview. Note: top board is a 12" V board, with a depth of 4" V cut and the depth of the top board is 8" to the V-point.

Actua Setting	Corn (2009)											
Week	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	13"	37"	37"	37"	8"	8"	32"	32"	32"	32"	32"	32"
2	13"	37"	37"	8"	8"	32"	32"	32"	32"	32"	32"	32"
3	37"	37"	37"	8"	8"	32"	32"	32"	32"	32"	32"	32"
4	37"	37"	37"	8"	8"	32"	32"	32"	32"	32"	32"	32"

Corn (2009) - Lakeview



Comments: The actual board setting after August might be wrong due to the loss of some field records.

Ohio Cropping and Yield Data

Table 6a. Cropping and yield data for Site 1 (Defiance, Ohio).

		2006		**2007**		**2008**		**2009**	
Crop									
Variety									
Planting Date									
Row Spacing									
Tillage	**Conventional**								
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**								
	Actual N#s/acre								
Post-plant N application	**Date**								
	Actual N#s/acre								
Phosphorus	**Actual P#s/acre**								
Potash	**Actual K#s/acre**								
Herbicide	**oz/acre**								
Insecticide	**oz/acre**								
Harvest date									
	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield									
Moisture									
Comments (hail, drought, heat, wind, etc.)									

Table 6b. Cropping and yield data for Site 2 (Napoleon, Ohio).

		2006		2007		2008		2009	
Crop									
Variety									
Planting Date									
Row Spacing									
Tillage	**Conventional**								
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**								
	Actual N#s/acre								
Post-plant N application	**Date**								
	Actual N#s/acre								
Phosphorus	**Actual P#s/acre**								
Potash	**Actual K#s/acre**								
Herbicide	**oz/acre**								
Insecticide	**oz/acre**								
Harvest date									
	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield									
Moisture									
Comments (hail, drought, heat, wind, etc.)									

Table 6c. Cropping and yield data for Site 3 (Dunkirk, Ohio).

		2006		2007		2008		2009	
Crop						Corn			
Variety									
Planting Date						5/29/08			
Row Spacing						30”			
Tillage	**Conventional**					Conventional			
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**								
	Actual N#s/acre					35			
Post-plant N application	**Date**								
	Actual N#s/acre					145			
Phosphorus	**Actual P#s/acre**					60			
Potash	**Actual K#s/acre**					120			
Herbicide	**oz/acre**								
Insecticide	**oz/acre**								
Harvest date						Oct 22			
	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield									
Moisture									
Comments (hail, drought, heat, wind, etc.)									

Table 6d. Cropping and yield data for Site 4 (Lakeview, Ohio).

		2006		2007		2008		2009	
Crop		Popcorn		Popcorn		Soybeans, corn belt		Popcorn	
Variety		VYP 322 Test Plot		VYP 213 V04001R		S289RR S2772RR		VYP 213	
Planting date		4/28/06		5/5/07		5/1/08, 5/6/08, 6/9/08		4/27/09	
Row spacing		30”		30”		7.5”		30”	
Tillage	**Conventional, Conservation, No Till**	No Till		No Till				Almost No Till	
Nitrogen									
Fall N application	**Date**								
	Actual N#s/ac	0		0				0	
Pre-plant N application	**Date**							4/25/09	
	Actual N#s/ac	0		0				140	
Post-plant N application	**Date**	6/10/06		5/28/07				6/12/09	
	Actual N#s/ac	120		175				50	
Phosphorus	**Actual P#s/ac**	0		0					
Potash	**Actual K#s/ac**	0		0					
Herbicide	**oz/ac**	LUMAX ATREX 3 qts 0.5#		LUMAX AATREX 3qt 0.5#		Round-up Power Max 3x22oz		LEXAR 3.5 qts	
Insecticide	**oz/ac**	FORCE 3.3#		FORCE Mustang MRX 4.4#		Warrior		FORCE 3.3#/ac	
Harvest date		Oct 24, Nov 2		Oct 29		Oct 2		Oct 27	
Drainage	**MD-managed drainage, CD-conventional drainage**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield				**194.1**	**197.7**	**124.3**	**139.3**		
Moisture				**14.3**	**15.3**	**19.2**	**19.6**		
Comments (hail, drought, heat, wind, etc.)									

Minnesota Site Descriptions

Table 7. Minnesota site descriptions.

Sites	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Description	**Dundas**	**Hayfield**	**Wilmont**	**Windom**
Managed drainage (acres)	6.6 ac	20 ac Site 1	13.5 ac	West Site: 51 ac East Site: 45 ac
Conventional drainage (acres)	15.6 ac Site 1	15 ac Site 2 20 ac Site 3	19.1 ac	Mid Site: 50 ac
Soil types	Dundas silt loam	Tripoli silty clay loam	Okabena	Nicollet Clay loam
Watershed name	Cannon River	Middle Zumbro	W Fork Des Moines-Head	Blue Earth River & Watonwan
30 year precipitation averages (inches)	31.64 in	30.14 in	27.79 in	29.00 in
Installation date of system month/ year	April 2007	April 2007	June 2007	Nov 2007
Depth of tile (feet)	4 ft	4 ft	4 ft	4 ft
Drainage coefficient (in)	≈ 1” u	½”	≈ ½” v	≈ ½” t
Tile spacing (ft)	40 ft	Site 1-2: 35 ft Site 3: 70 ft	80 ft	75 ft
New or retrofit system	Retrofit	Retrofit	Retrofit	New
Installation date of control structure	June 2007	June 2007	June 2007	July 2008
Laterals on the contour (Yes or No)?	Yes	Yes	Yes	Yes

u ¾” spacing @ 4’ depth= 60’, ½” spacing @ 4’ depth = 77’ for Dundas silt loam soil
v ½” spacing @ 4’ depth = 69’ for Waldorf soil
t ½” spacing @ 4’ depth = 85’ for Nicollet clay loam soil

Figure 62. Dundas site soil & tile map.

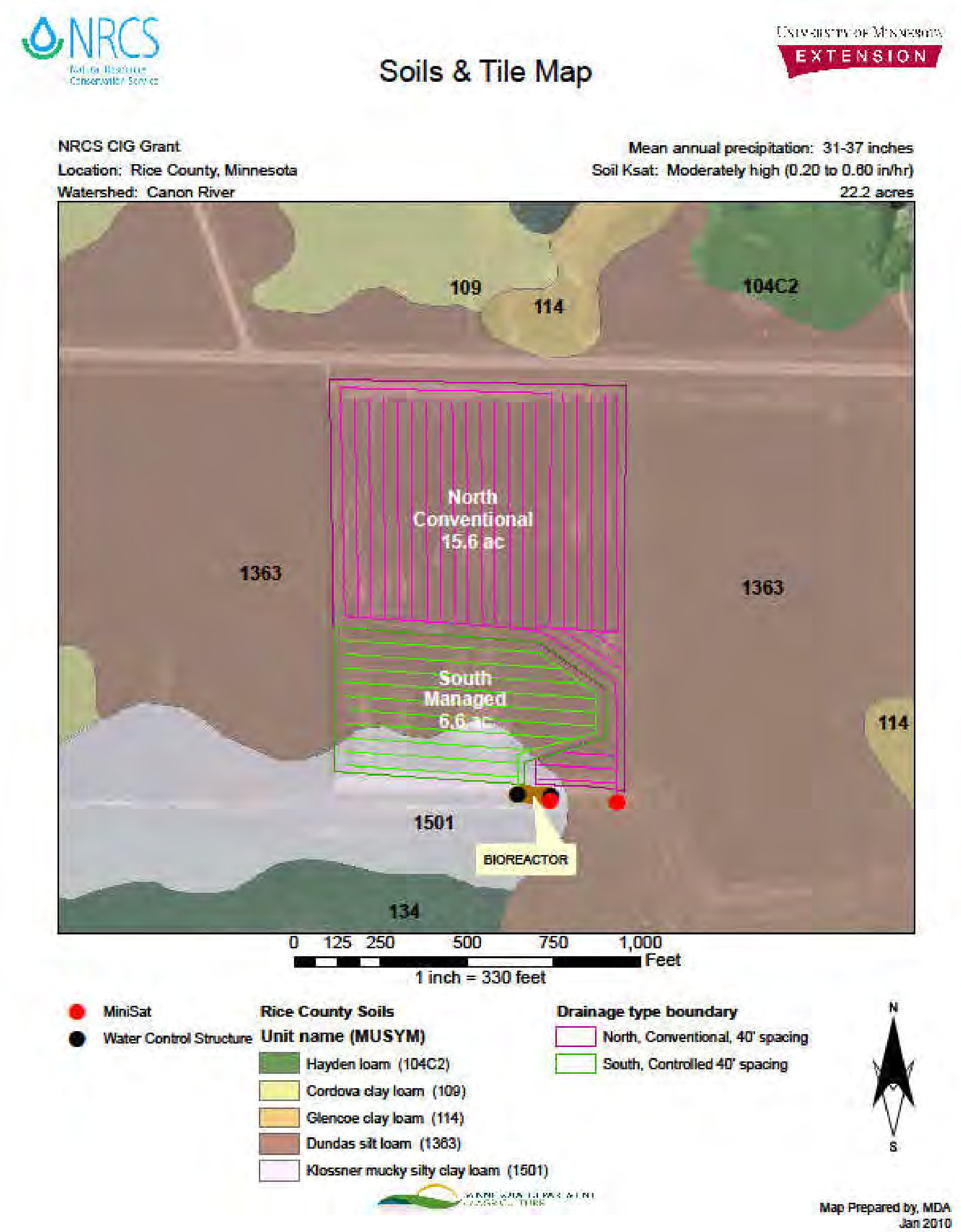


Figure 63. Dundas site topographical map.

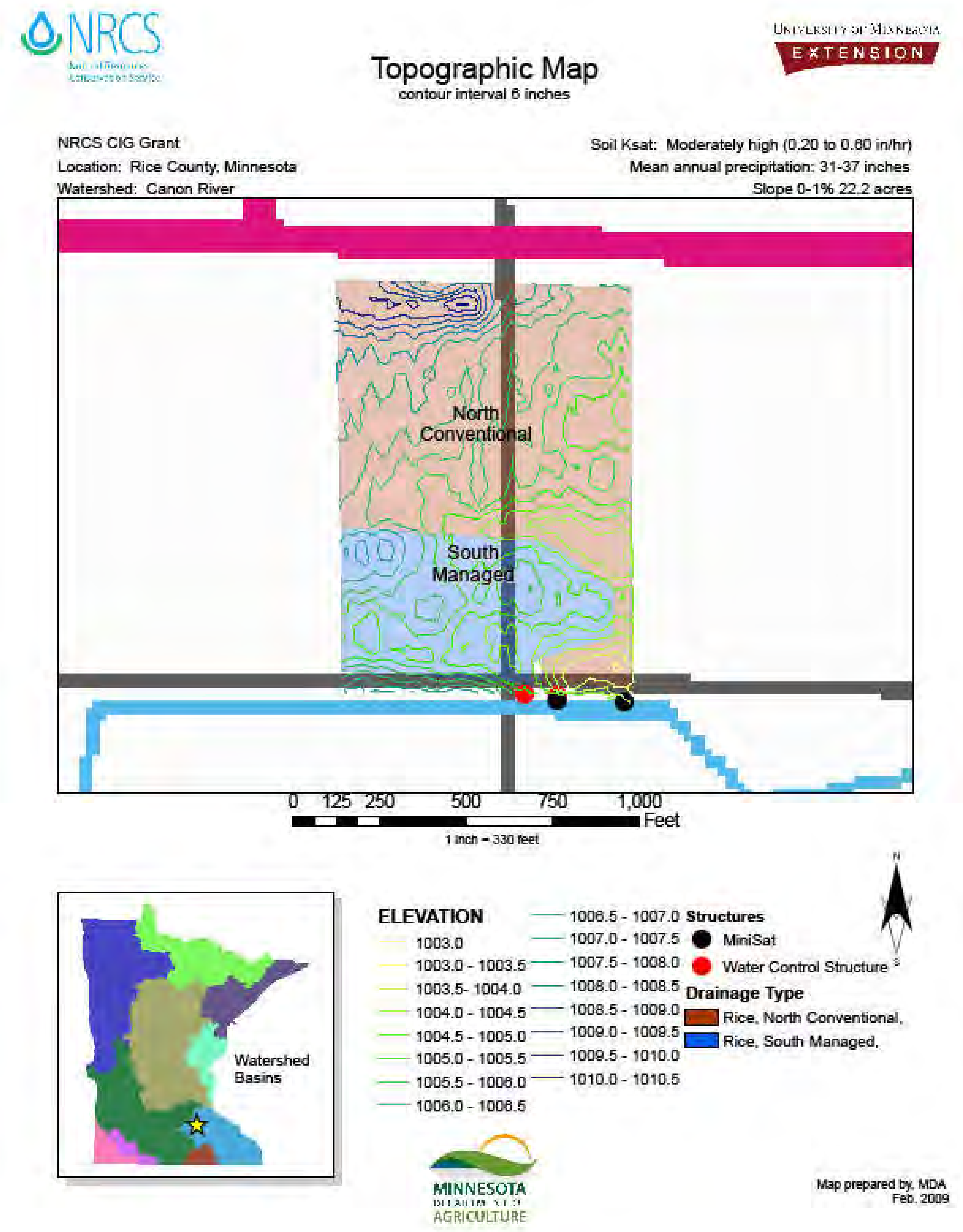


Figure 64. Dundas zone of influence map.

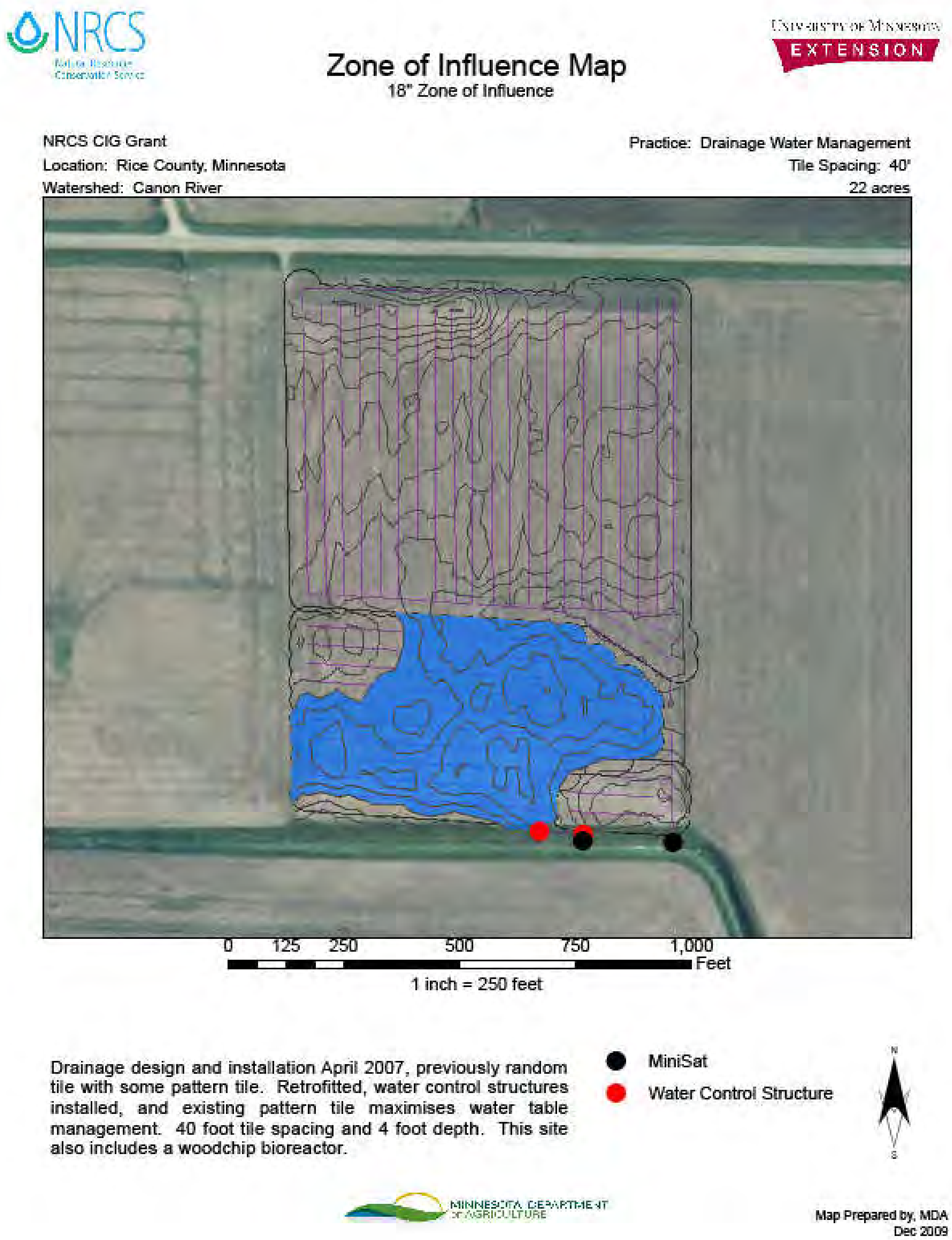


Figure 65. Hayfield site soil & tile map.

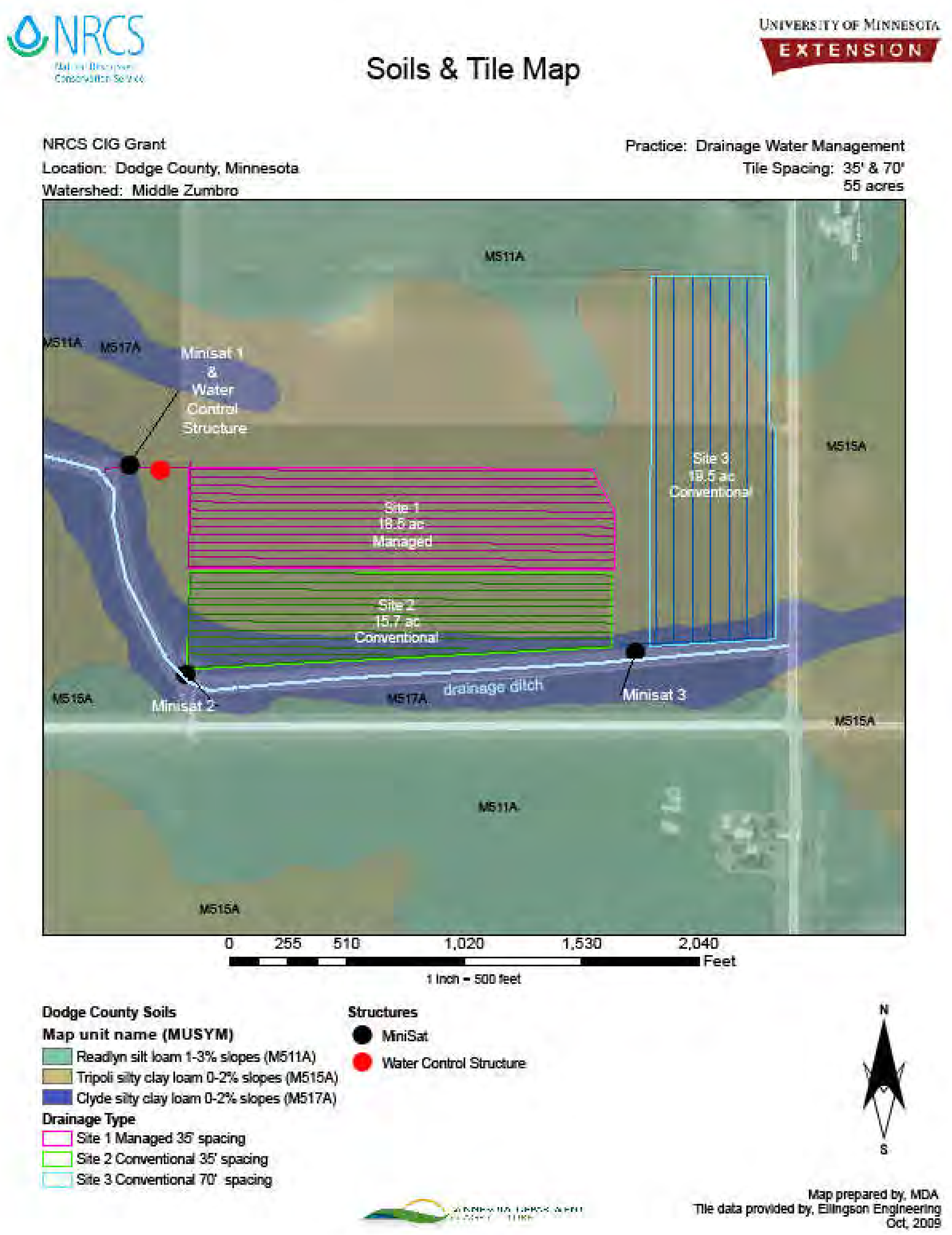


Figure 66. Hayfield site topographic map.

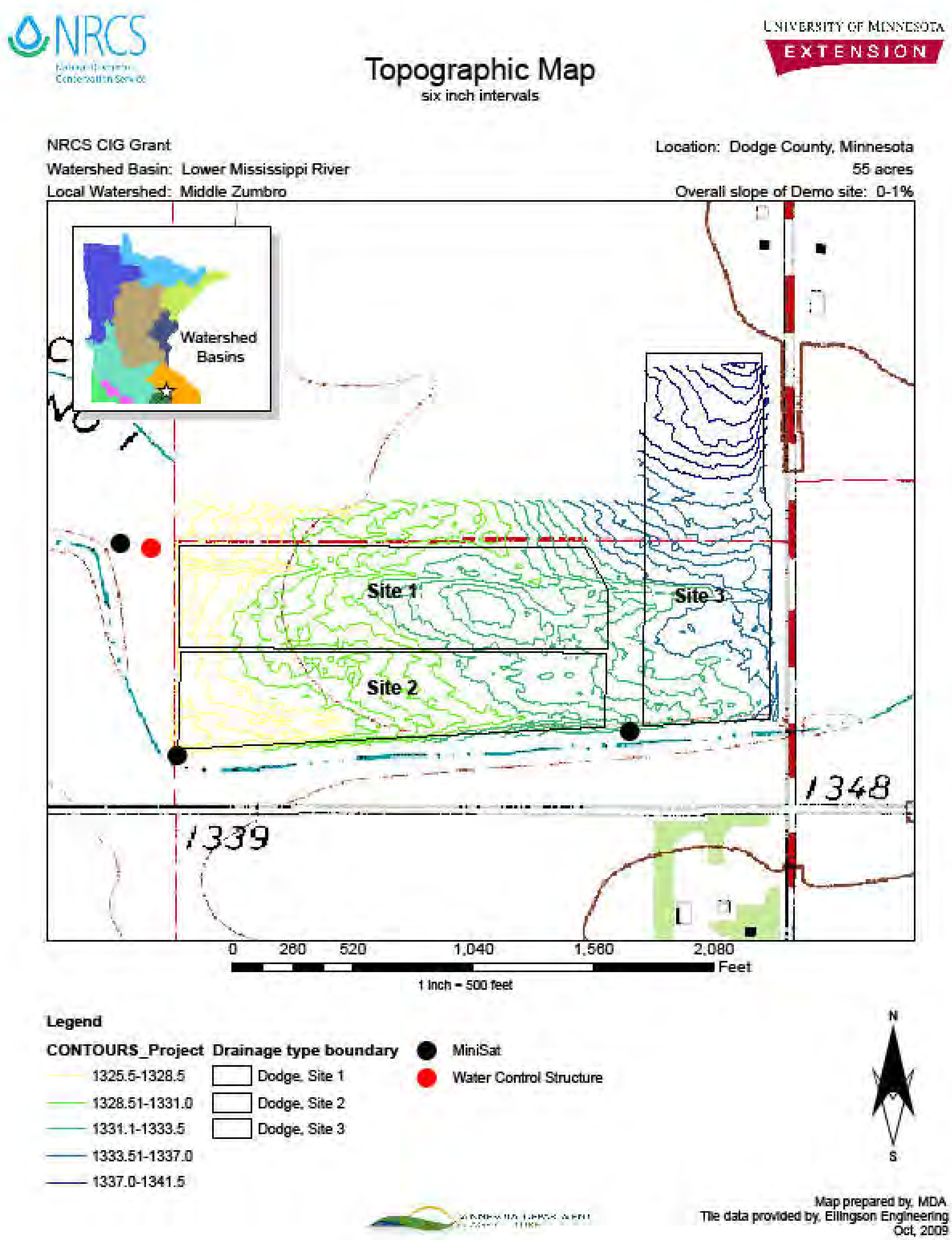


Figure 67. Hayfield zone of influence.

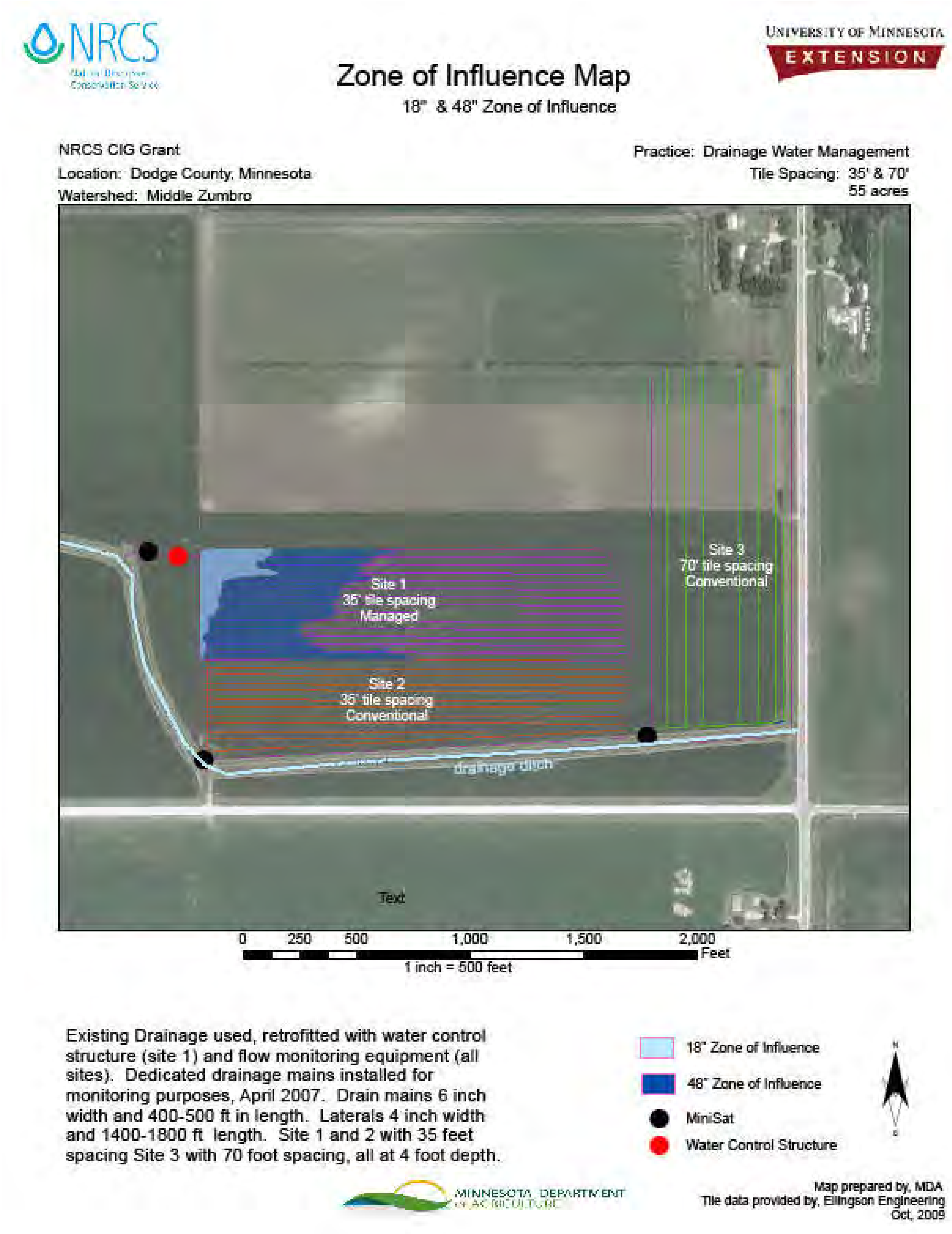


Figure 68. Wilmont site soil and tile map.

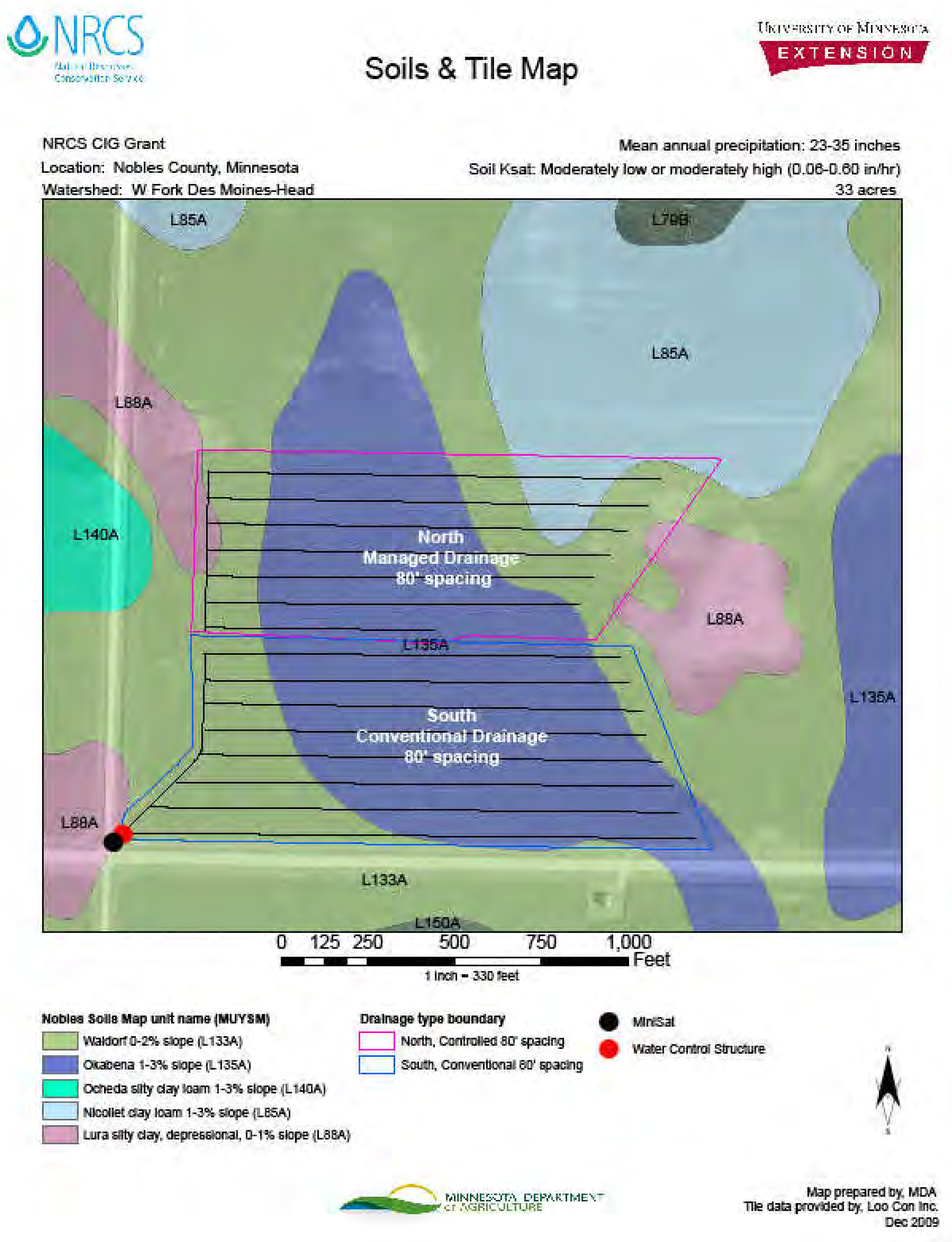


Figure 69. Wilmont site topographical map.

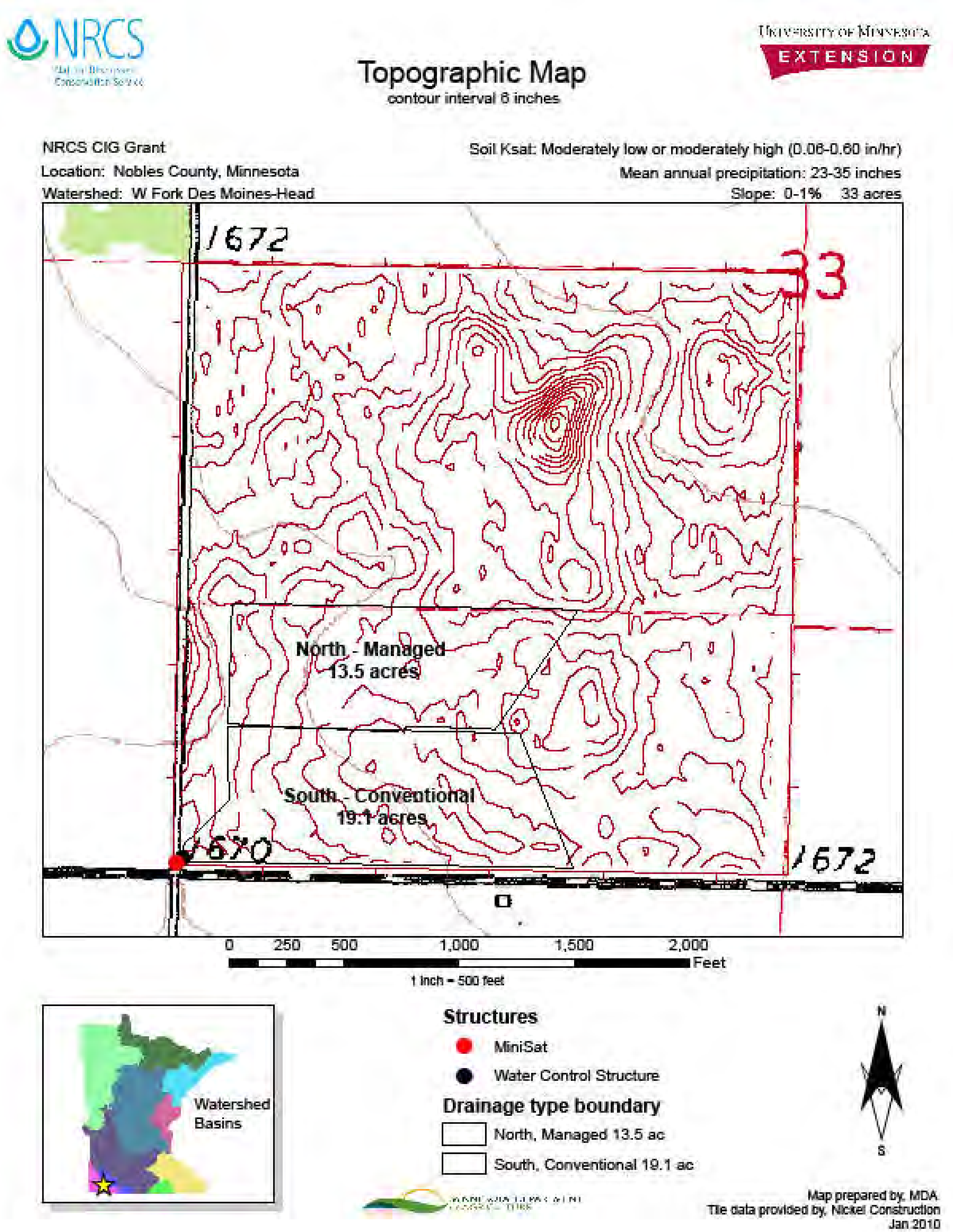


Figure 70. Wilmont zone of influence map.

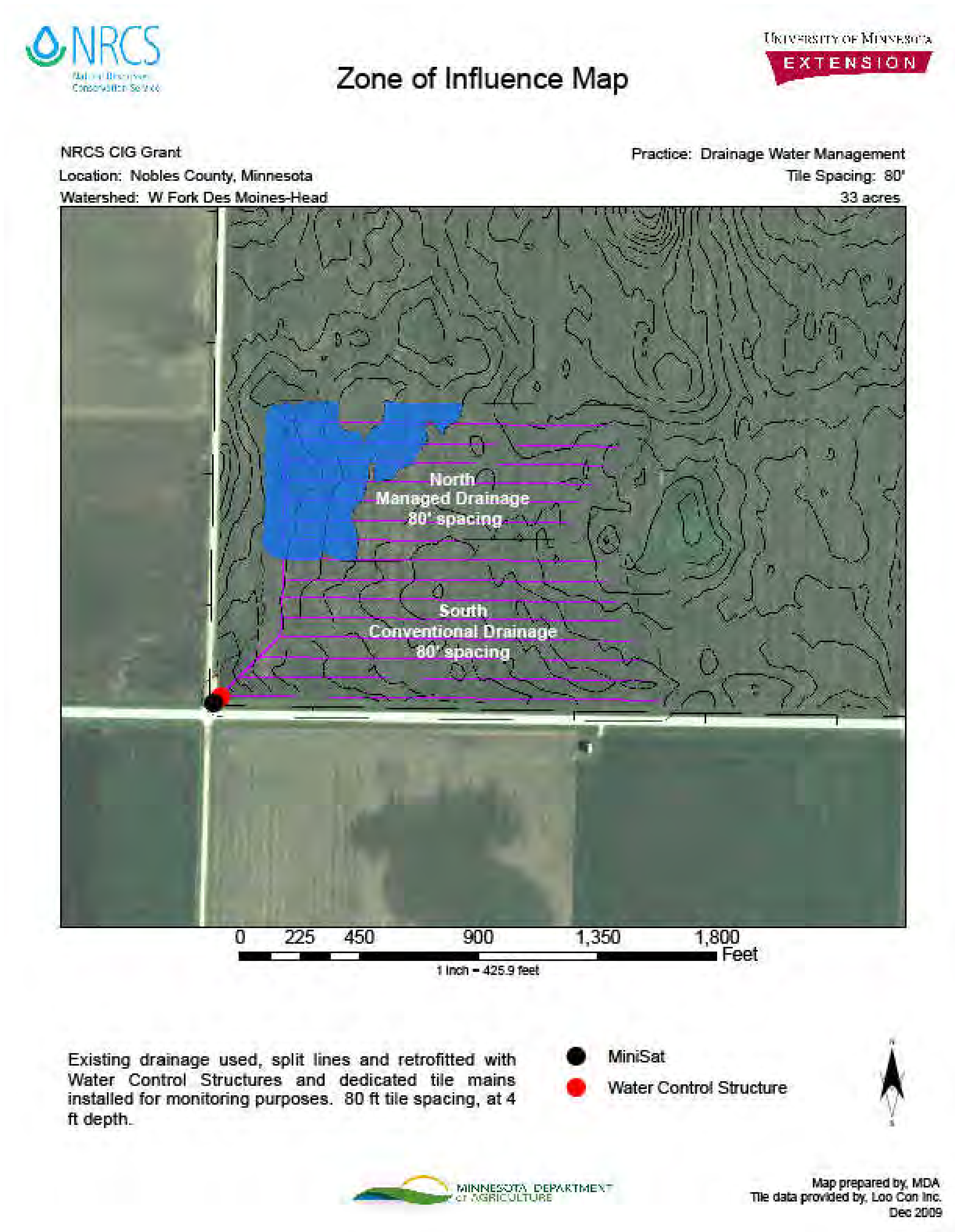


Figure 71. Windom site soil and tile map.

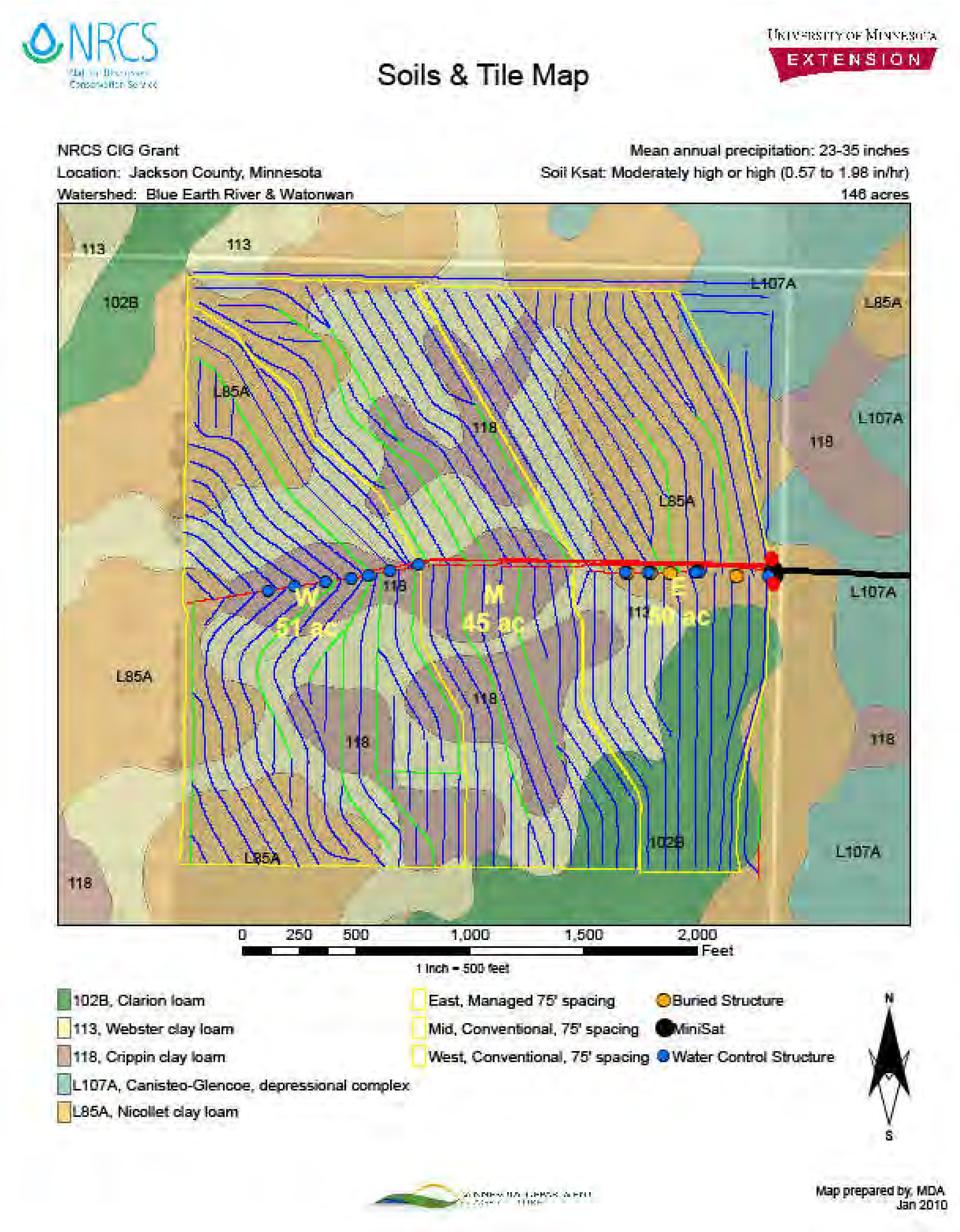


Figure 72. Windom site topographical map.

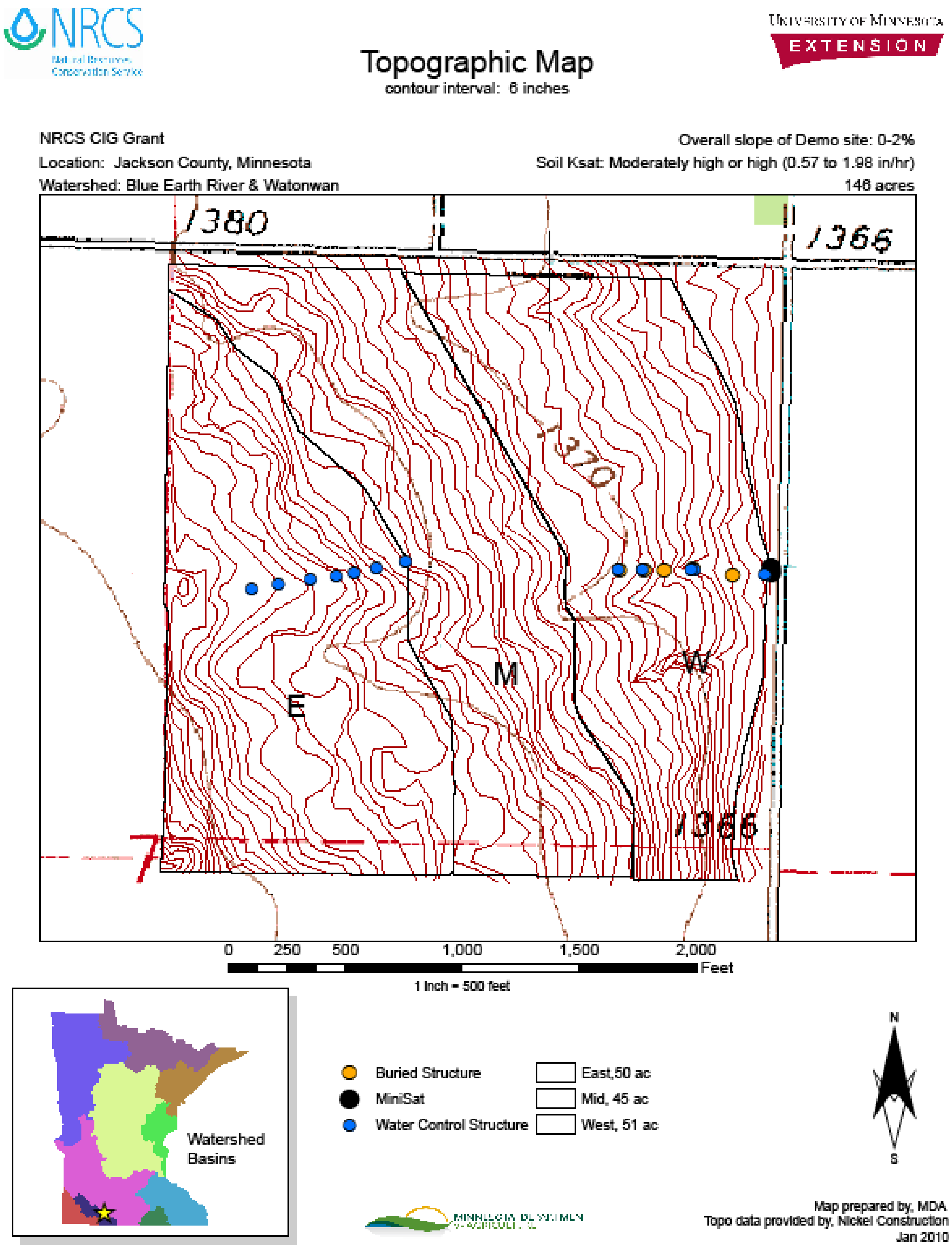
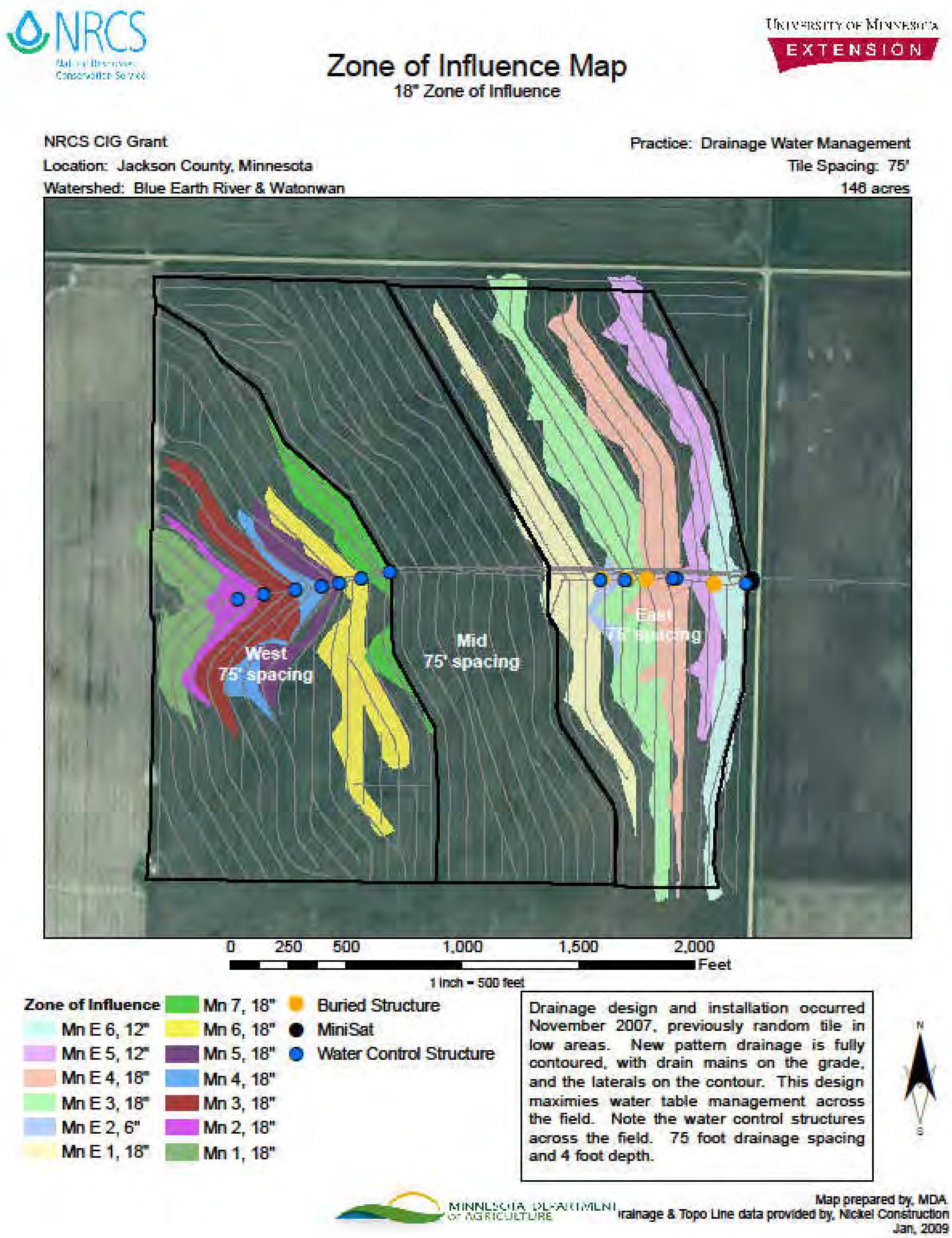


Figure 73. Windom zone of influence map.



Minnesota Water Management Plan

Figure 74. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Dundas.

Crop: 2008	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	48	24	24	24	24	24	48	6	6
2	6	6	6	48	24	24	24	24	24	48	6	6
3	6	6	6	48	24	24	24	24	48	48	6	6
4	6	6	6	48	24	24	24	24	48	48	6	6
Crop: 2009	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	36	24	24	24	24	24	48	6	6
2	6	6	6	36	24	24	24	24	24	48	6	6
3	6	6	6	36	24	24	24	24	48	48	6	6
4	6	6	6	36	24	24	24	24	48	48	6	6
Water Height in Control Structure (inch)												

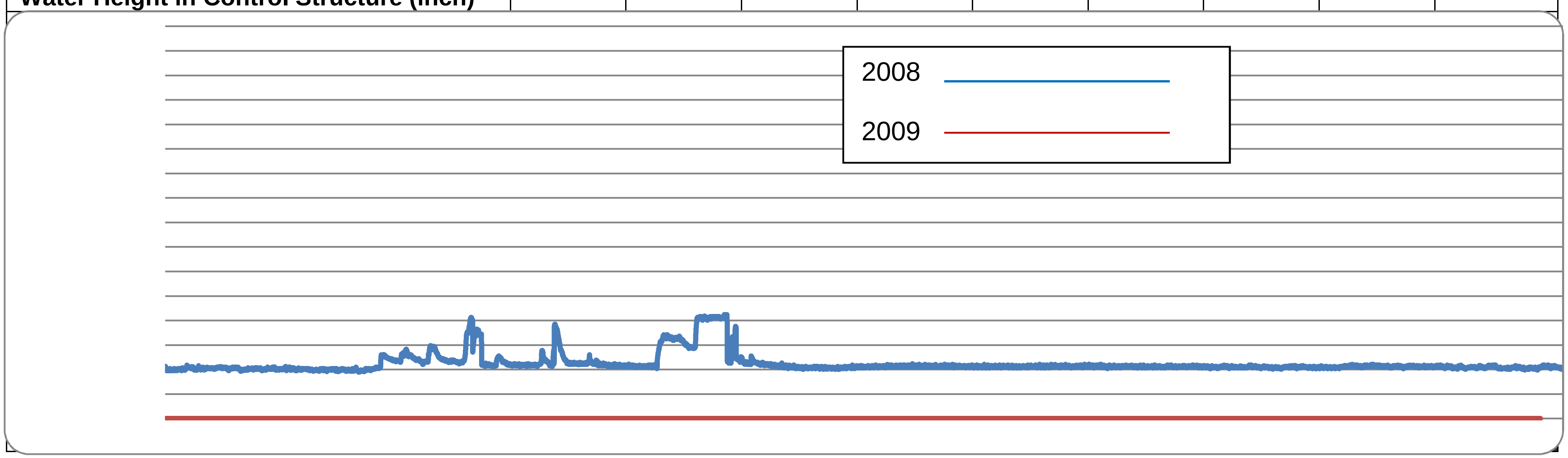


Figure 75. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Hayfield.

Crop: 2008	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	48	24	24	24	24	24	48	6	6
2	6	6	6	48	24	24	24	24	24	48	6	6
3	6	6	6	48	24	24	24	24	48	48	6	6
4	6	6	6	48	24	24	24	24	48	48	6	6
Crop: 2009	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	48	24	24	24	24	24	48	6	6
2	6	6	6	48	24	24	24	24	24	48	6	6
3	6	6	6	48	24	24	24	24	48	48	6	6
4	6	6	6	48	24	24	24	24	48	48	6	6
Water Height in Control Structure (inch)												

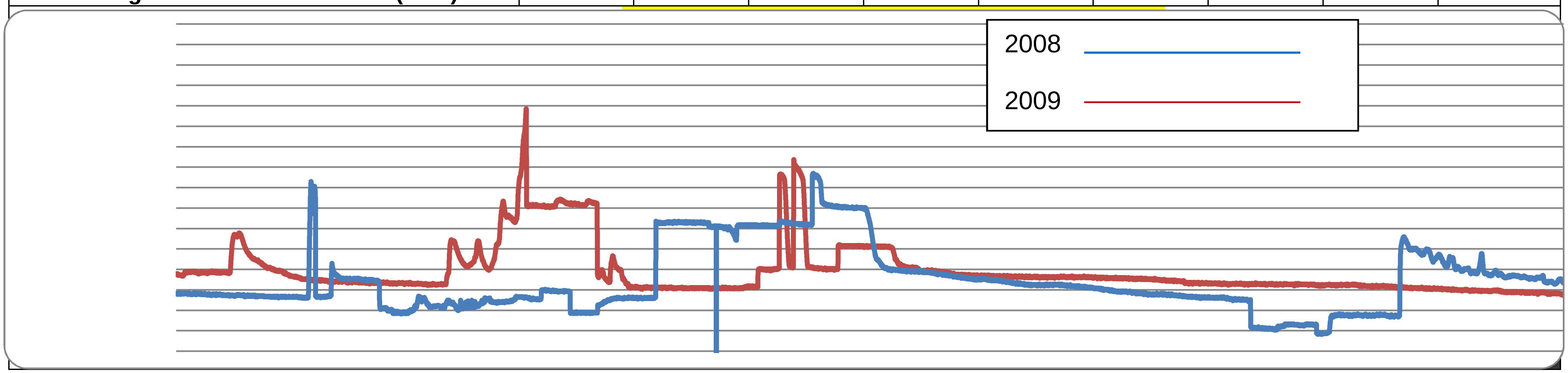


Figure 76. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Wilmont.

Crop: 2008	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	48	24	24	24	24	24	48	6	6
2	6	6	6	48	24	24	24	24	24	48	6	6
3	6	6	6	48	24	24	24	24	48	48	6	6
4	6	6	6	48	24	24	24	24	48	48	6	6
Crop: 2009	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	48	24	24	24	24	24	48	6	6
2	6	6	6	48	24	24	24	24	24	48	6	6
3	6	6	6	48	24	24	24	24	48	48	6	6
4	6	6	6	48	24	24	24	24	48	48	6	6
Water Height in Control Structure (inch)												

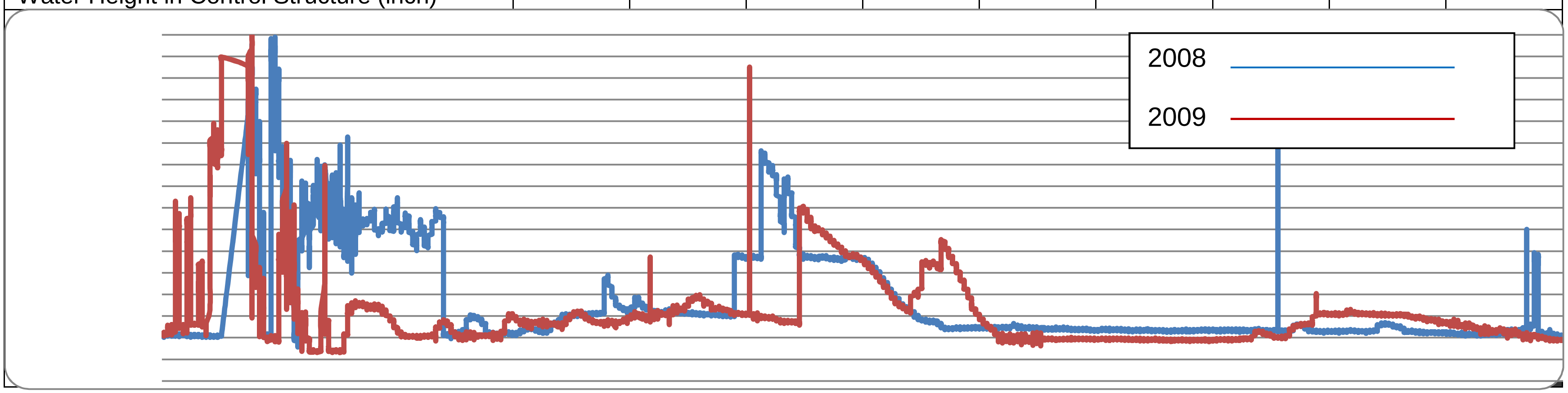
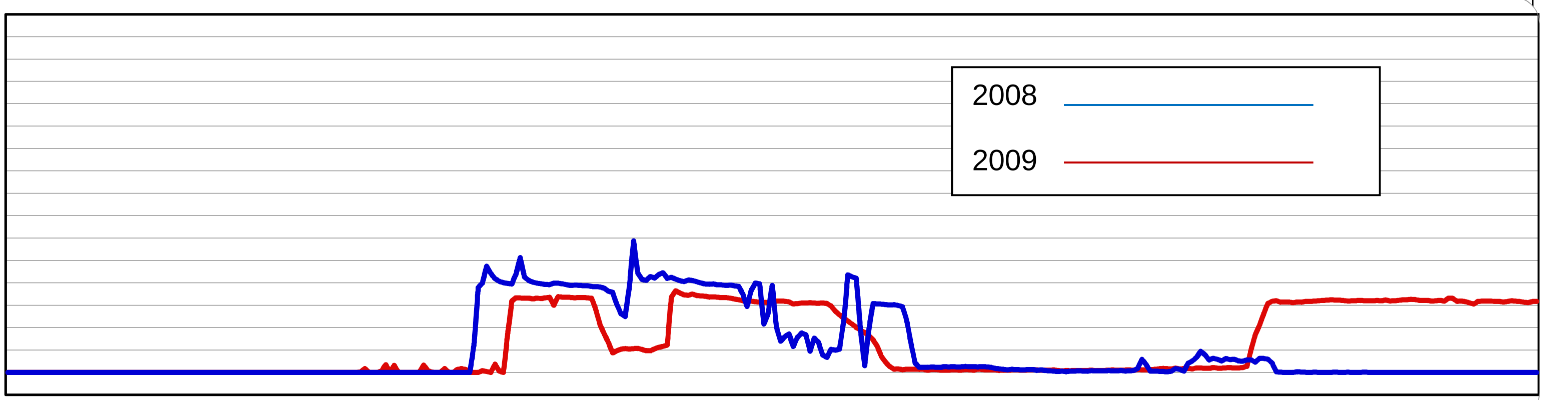


Figure 77. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Windom.

Crop: 2008	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	----	----	----	----	----	----	24	24	24	48	6	6
2	----	----	----	----	----	----	24	24	24	48	6	6
3	----	----	----	----	----	----	24	24	48	48	6	6
4	----	----	----	----	----	----	24	24	48	48	6	6
Crop: 2009	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	6	6	6	48	24	24	24	24	24	48	6	6
2	6	6	6	48	24	24	24	24	24	48	6	6
3	6	6	6	48	24	24	24	24	48	48	6	6
4	6	6	6	48	24	24	24	24	48	48	6	6
Water Height in Control Structure (inch)												



Comments Water Control Structures installed July 2008

Minnesota Cropping and Yield Data

Table 8a. Cropping and yield data for Site 1 (Dundas, Minnesota).

		2006		2007		2008		2009	
Crop		-------		Soybeans		Corn		Soybeans	
Variety		-------		N K 21 N6		Pioneer 37Y14		Prairie 2056 RR	
Planting Date		-------		5-27-07		4-24-08		5-30-09	
Row Spacing		-------		30"		30"		30"	
Tillage	Fall tillage: V ripper Spring tillage: Field cultivator			Injected Dairy Manure in Fall					
Nitrogen		-------		---------		---------		Anhydrous	
Fall N application	**Date**	-------		11-10-07		---------		11-12-09	
	Actual N#s/acre	-------		136		---------		150	
Pre-plant N application	**Date**	-------		---------		4-18-08		---------	
	Actual N#s/acre	-------		---------		60		---------	
Post-plant N application	**Date**	-------		---------		---------		---------	
	Actual N#s/acre	-------		---------		---------		---------	
Phosphorus	**Actual P#s/acre**	-------		82		---------		---------	
Potash	**Actual K#s/acre**	-------		204		---------		---------	
Herbicide	**oz/acre**	-------		64 oz. split application Glyphosate		16 oz. pre-emergent Harness 32 oz. Post-emergent Glyphosate		64 oz. split application Glyphosate	
Insecticide	**oz/acre**	-------		Warrior		---------		Warrior	
Harvest date		-------		Oct 10		Oct 25		Oct 29	
MD-managed drainage CD-conventional drainage		**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield						180	185	54	54
Moisture		-------		12%		23%		14%	
Comments (hail, drought, heat, wind, etc.)	9500 gallons cow manure applied Fall 2007			Dry summer wet August		Dry Summer 23,000 final population of corn		Replant soybeans 5-30-09	

Table 8b. Cropping and yield data for Site 2 (Hayfield, Minnesota).

<table>
<tr><th colspan="2"></th><th colspan="2">2006</th><th colspan="3">2007</th><th colspan="3">2008</th><th colspan="3">2009</th></tr>
<tr><td colspan="2">Crop</td><td colspan="2">Soybeans</td><td colspan="3">Corn</td><td colspan="3">Soybeans</td><td colspan="3">Corn</td></tr>
<tr><td colspan="2">Variety</td><td colspan="2">Dynagro 33x19</td><td colspan="3">LG 2496</td><td colspan="3">Gold Country 882DRD</td><td colspan="3">DeKalb 52-59 VTS</td></tr>
<tr><td colspan="2">Planting Date</td><td colspan="2">May 8</td><td colspan="3">April 20</td><td colspan="3">May 16</td><td colspan="3">April 16</td></tr>
<tr><td colspan="2">Row Spacing</td><td colspan="2">20”</td><td colspan="3">20”</td><td colspan="3">20”</td><td colspan="3">20”</td></tr>
<tr><td>Tillage</td><td colspan="12">Fall chisel plow, disk ripper and spring field cultivator</td></tr>
<tr><td colspan="2">Nitrogen</td><td colspan="2">Anhydrous</td><td colspan="3">-------</td><td colspan="3">Anhydrous</td><td colspan="3">-------</td></tr>
<tr><td>Fall N application</td><td>Date</td><td colspan="2">November</td><td colspan="3">-------</td><td colspan="3">November</td><td colspan="3">-------</td></tr>
<tr><td colspan="2">Actual N#s/acre</td><td colspan="2">175</td><td colspan="3">-------</td><td colspan="3">175</td><td colspan="3">-------</td></tr>
<tr><td>Pre-plant N application</td><td>Date</td><td colspan="2">-------</td><td colspan="3">at planting</td><td colspan="3">-------</td><td colspan="3">at planting</td></tr>
<tr><td colspan="2">Actual N#s/acre</td><td colspan="2">-------</td><td colspan="3">8 gal 10-30-0</td><td colspan="3">-------</td><td colspan="3">8 gal 10-34-0</td></tr>
<tr><td>Post-plant N application</td><td>Date</td><td colspan="2">-------</td><td colspan="3">-------</td><td colspan="3">-------</td><td colspan="3">-------</td></tr>
<tr><td colspan="2">Actual N#s/acre</td><td colspan="2">-------</td><td colspan="3">-------</td><td colspan="3">-------</td><td colspan="3">-------</td></tr>
<tr><td>Phosphorus</td><td>Actual P#s/acre</td><td colspan="5">125 (MAP or DAP)</td><td colspan="3">125 (MAP or DAP)</td><td colspan="3">125 (MAP or DAP)</td></tr>
<tr><td>Potash</td><td>Actual K#s/acre</td><td colspan="2">200</td><td colspan="3">-------</td><td colspan="3">200</td><td colspan="3">-------</td></tr>
<tr><td>Herbicide</td><td>oz/acre</td><td colspan="2">Roundup 40g</td><td colspan="3">Harness X-TRA</td><td colspan="3">Roundup 40g</td><td colspan="3">Harness X-TRA</td></tr>
<tr><td>Insecticide</td><td>oz/acre</td><td colspan="2">Warrior</td><td colspan="3">Roundup 22oz</td><td colspan="3">Warrior</td><td colspan="3">Roundup 22oz</td></tr>
<tr><td colspan="2">Harvest date</td><td colspan="2">-------</td><td colspan="3">-------</td><td colspan="3">Oct 3</td><td colspan="3">Nov 10</td></tr>
<tr><td colspan="2">MD-managed drainage
CD-conventional drainage</td><td>MD</td><td>CD</td><td>MD</td><td>CD</td><td>CD</td><td>MD</td><td>CD</td><td>CD</td><td>MD</td><td>CD</td><td>CD</td></tr>
<tr><td>Yield</td><td></td><td></td><td></td><td>204</td><td>204</td><td>205</td><td>51</td><td>57</td><td>53</td><td>207</td><td>197</td><td>204</td></tr>
<tr><td>Moisture</td><td></td><td colspan="2">-------</td><td colspan="3">-------</td><td colspan="3">-------</td><td colspan="3">-------</td></tr>
<tr><td>Comments
(hail, drought, heat, wind, etc.)</td><td></td><td colspan="2">Sept hail</td><td colspan="3"></td><td colspan="3">Drought</td><td colspan="3">Drought, cool summer</td></tr>
</table>

Table 8c. Cropping and yield data for Site 3 (Wilmont, Minnesota).

		2006		2007		2008		2009	
Crop		corn		corn		corn		corn	
Variety		-------		Cropland 421		Dekalb 52-43		Dekalb 46-60	
Planting Date		-------		May 2		May 1		April 24	
Row Spacing		-------		30 in		30 in		30 in	
Tillage	Primary tillage consisted of a single pass fall chisel plow; secondary tillage consisted of a single pass spring field cultivation followed by planting.								
Nitrogen				DAP					
Fall N application	**Date**	-------		Oct 30		Nov 3		No application	
	Actual N#s/acre	-------		100 lbs/ac anhydrous		155 lbs/ac anhydrous			
Pre-plant N application	**Date**	-------		4/30/07		No application		4/23/09	
	Actual N#s/acre	-------		200 lbs/ac				145 lbs/ac anhydrous	
At-planting N application	**Date**	-------		May 2		May 1		April 24	
	Actual N#s/acre	-------		5 lbs/ac		5 lbs/ac		5 lbs/ac	
Phosphorus	**Actual P#s/acre**	-------		17 lbs/ac		17 lbs/ac		17 lbs/ac	
Potash	**Actual K#s/acre**	-------							
Herbicide	**oz/acre**	-------		Roundup		Roundup		Roundup	
Insecticide	**oz/acre**	-------							
Harvest date		-------		Oct 11		Oct 4		Nov 10	
MD-managed drainage CD-conventional drainage		**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield						168	173	173	175
Moisture		-------		-------		-------		21	
Comments (hail, drought, heat, wind, etc.)				No tile flow after installation of the site-no rain					

Table 8d. Cropping and yield data for Site 4 (Windom, Minnesota).

		2006	2007	2008	2009
Crop		Soybeans	Corn	Soybeans	Corn
Variety		Pioneer 92M32 & Midwest 2332	Dekalb 51-45, Dekalb 52-47, Dekalb 51-39, Dekalb 4622 (Replant)	Stine 1932-4	Dekalb 52-59, Dekalb 53-41 & Pioneer 36V51
Planting Date		5/20/06	5/1/07	5/20/08	4/21/09
Row Spacing		30-inch	30-inch	30-inch	30-inch
Tillage	**Conventional**				
	Conservation			X	X
	Ridge- Till	X	X		
Nitrogen		-------	NH3	-------	Manure & NH3
Fall N application	**Date**	-------	-------	-------	Nov-08 (100 ac manure)
	Actual N #s/acre	-------	-------	-------	45#
Pre-plant N application	**Date**	-------	-------	-------	March-09 (140 ac manure) & April-09 (65 ac dry fert)
Actual N #s/acre		-------	-------	-------	45# (manure) & 50# (dry fert)
Post-plant N	**Date**	-------	Side dress anhydrous	-------	Side dress anhydrous
Actual N #s/acre		-------	125#	-------	125#
Phosphorus	**Actual P #s/acre**	-------	40#	-------	135#(manure-100 ac) 96#(manure on 141 acres) 90# (DAP on 65 ac)
Potash	**Actual K #s/acre**	-------	62#	-------	135#(manure-100ac)90#(manure on 141acres) 100# (Potash on 65 ac)
Herbicide	**oz/acre**	Glyphosate 5.5pts/acre	2-4D 0.5 pt Surpass 1.5pts; Glyphosate 2.5pts;	Glyphosate 32oz;Glyphosate 32 oz; Fusilade 2 oz.	Surpass 2pts; Banvel 0.5pts; Touchdown 38 oz; 2-4D 0.4pts
Insecticide	**oz/acre**	Lorsban 1pt/acre	-------	Warrior 1.2 oz	N/A
Harvest date		N/A	Oct 26	Oct 3	Nov 20
MD-managed drainage CD-conventional drainage		**MD** / **CD**	**MD** / **CD**	**E** / **M** / **W**	**E** / **M** / **W**
Yield		48.6	177	46 / 48 / 49	185 / 187 / 187
Moisture		-------	16%	N/A	21%
Comments (hail, drought, heat, wind, etc.)					

Illinois Site Descriptions

Table 9. Illinois site descriptions.

Sites	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Description	**Hume N**	**Hume S**	**Barry**	**Enfield**
Managed drainage (acres)	38	20	14	40
Conventional drainage (acres)	37	12	9	40
Soil types	Drummer silty clay loam	Drummer silty clay loam and Dana silt loam	Orion silt loam, Haymond silt loam, and Twomile Silt loam	Patton silty clay loam and Montgomery silty clay
Watershed name	Clark Branch-Brushy Fork	Clark Branch-Brushy Fork	Headwaters Kiser Creek	Gowdy Creek-Lost Creek
10 or 30 year precipitation averages	38.8	38.8	38.4	45.0
Installation date of system month/ year	November 2004	November 2007	November 2004	March 2007
Depth of tile	42-48	42-48	42-48	30-36
Drainage coefficient (in)	0.375	1.5	0.375	0.75
Tile spacing	100	50	60-70	40
New or retrofit system	New	New	Manage system new	New
Installation date of control structure	November 2004	November 2007	November 2004	March 2007
Laterals on the contour (Yes or No)?	No	No	No	Field flat

Figure 78. Hume N site soil map.

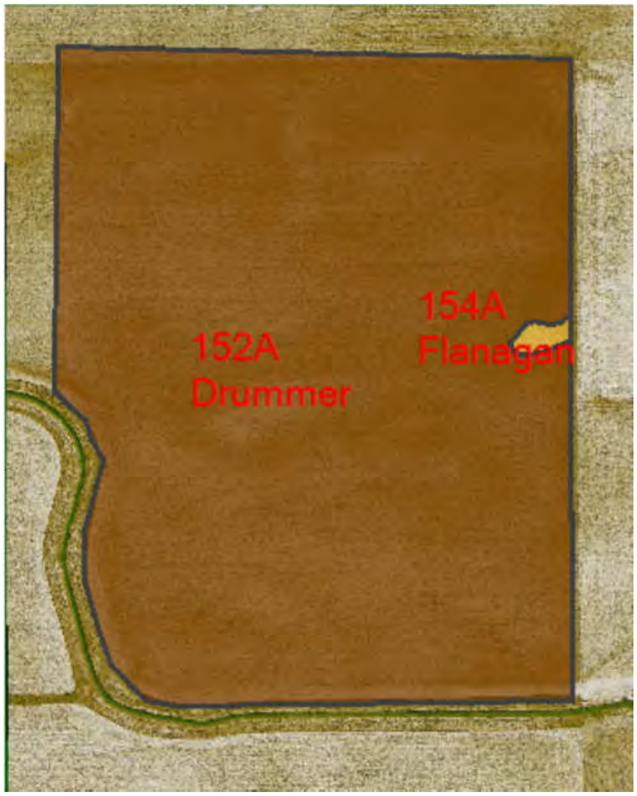


Figure 79. Hume N site tile map.

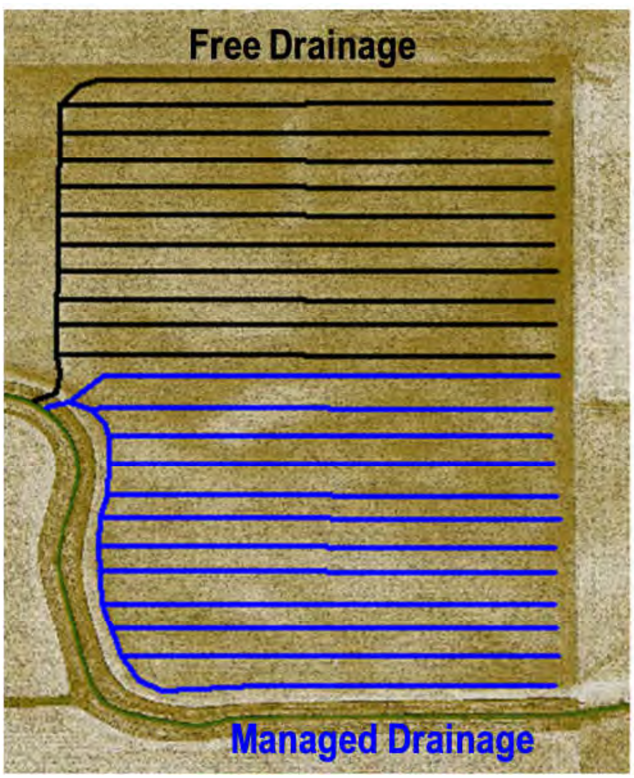


Figure 80. Hume N site topographical map.

Figure 81. Hume N site aerial map.

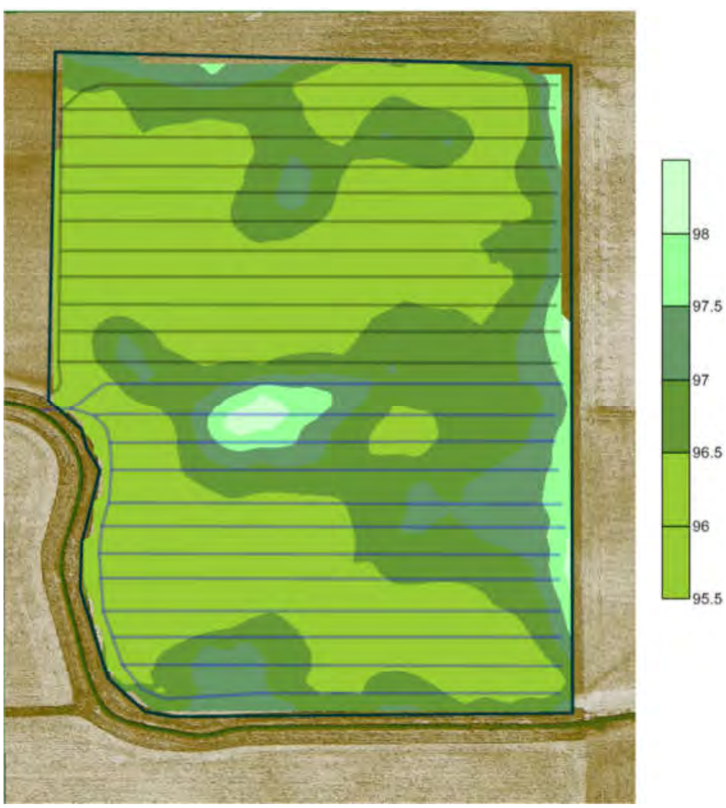


Figure 82. Hume S site soil map.

Figure 83. Hume S site tile map.

Figure 84. Hume S site topographical map.

Figure 85. Hume S site aerial map.

Figure 86. Barry site soil map.

Figure 87. Barry site tile map.

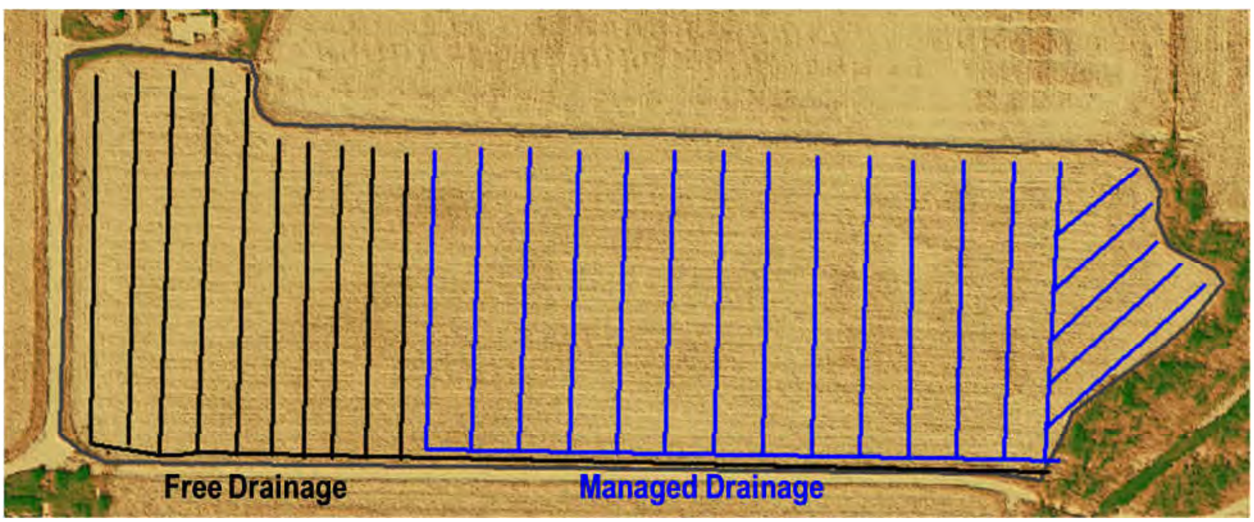


Figure 88. Barry site topographical map.

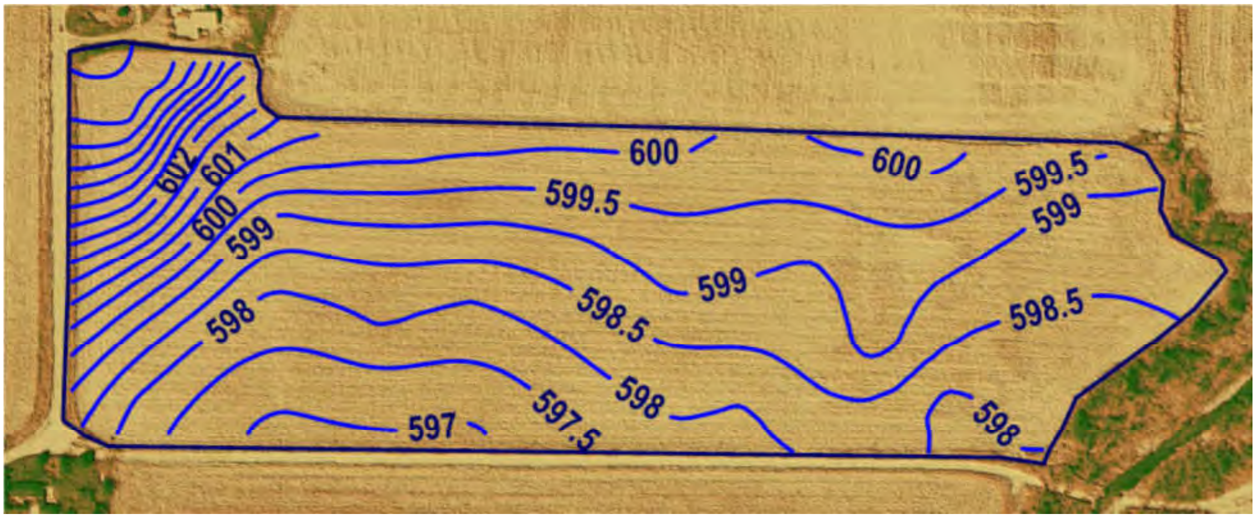


Figure 89. Barry site aerial map.

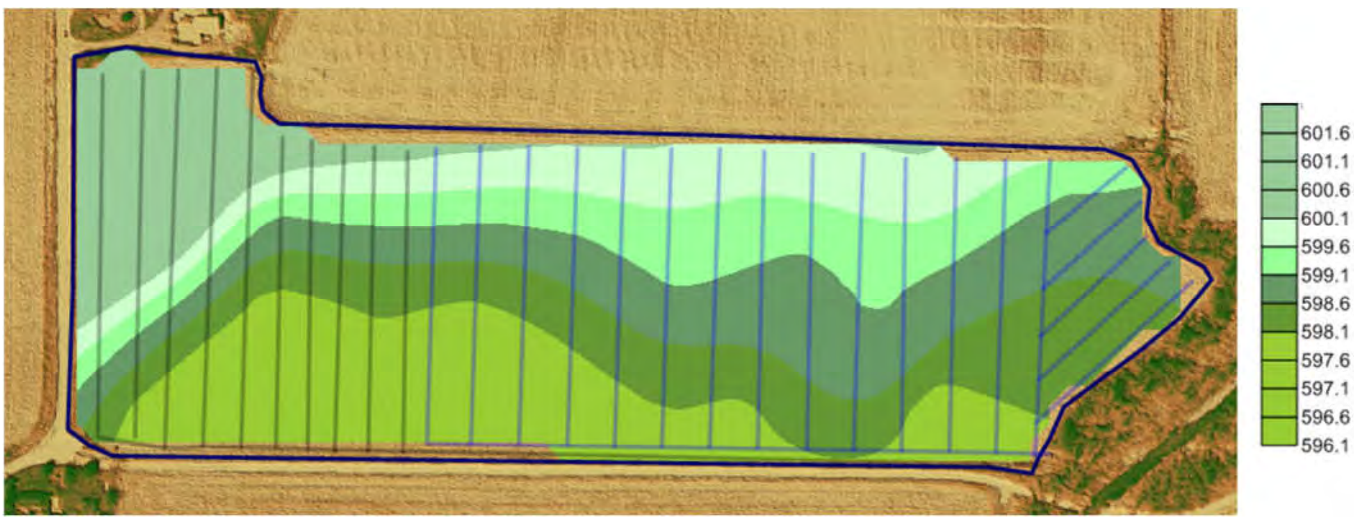


Figure 90. Enfield site soil map.

Figure 91. Enfield site tile map.

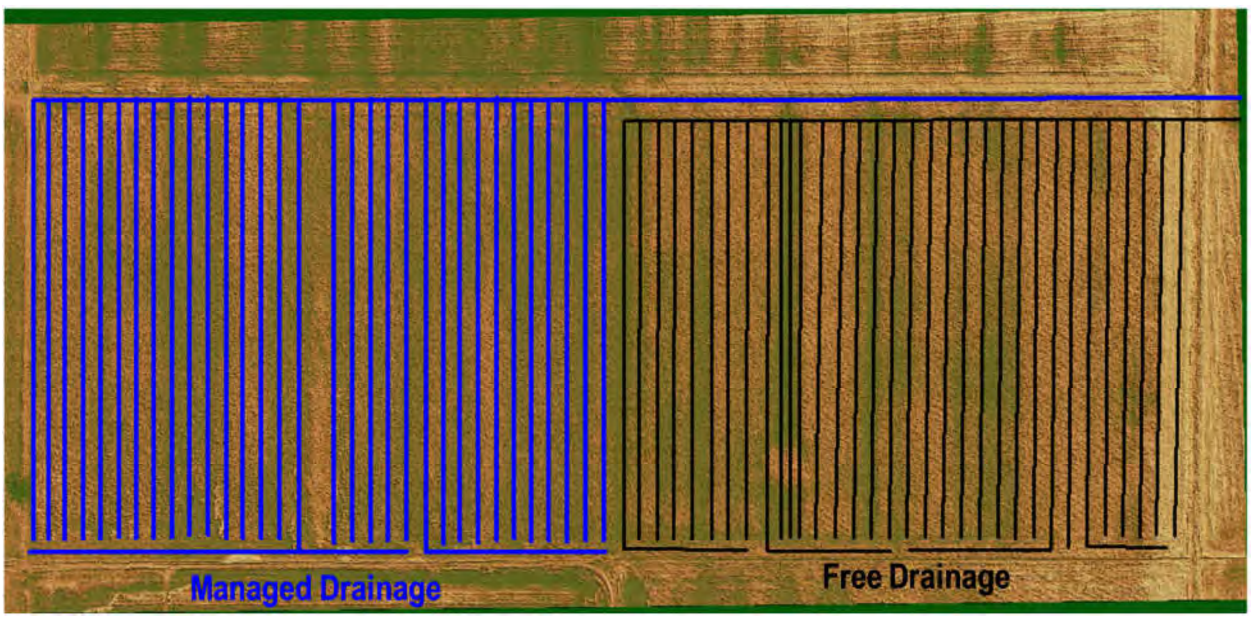
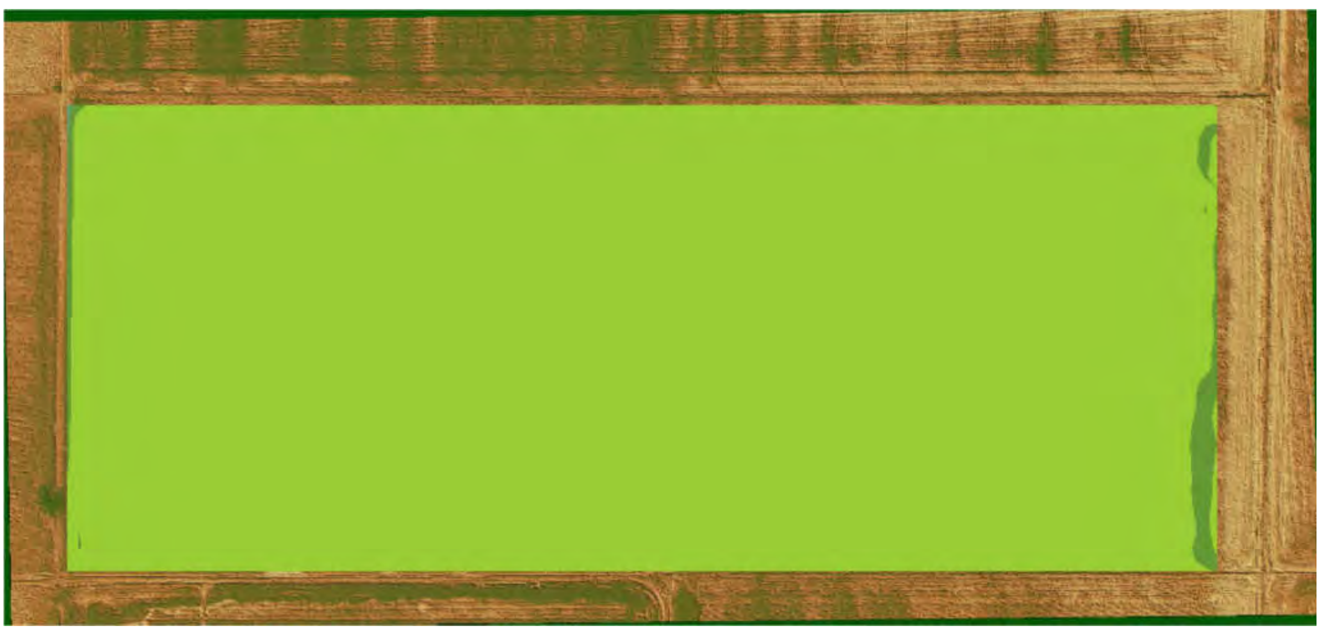


Figure 92. Enfield site topographical map.

Figure 93. Enfield site aerial map.



Illinois Water Management Plan

Figure 94. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Hume N.

Crop:	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
2	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
3	***12”***	***12”***	***24”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
4	***12”***	***12”***	***24”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
Crop:	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
2	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
3	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
4	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
Drain Depth												

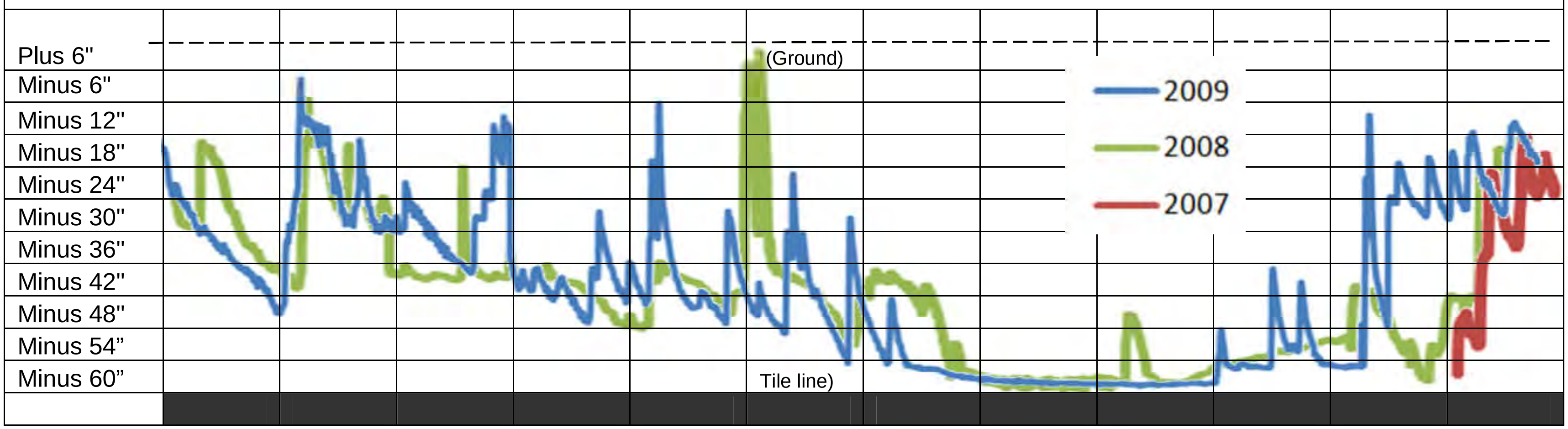


Figure 95. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Hume S.

Crop:	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
2	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
3	***12"***	***12"***	***24"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
4	***12"***	***12"***	***24"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
Crop:	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
2	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
3	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
4	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
Drain Depth												

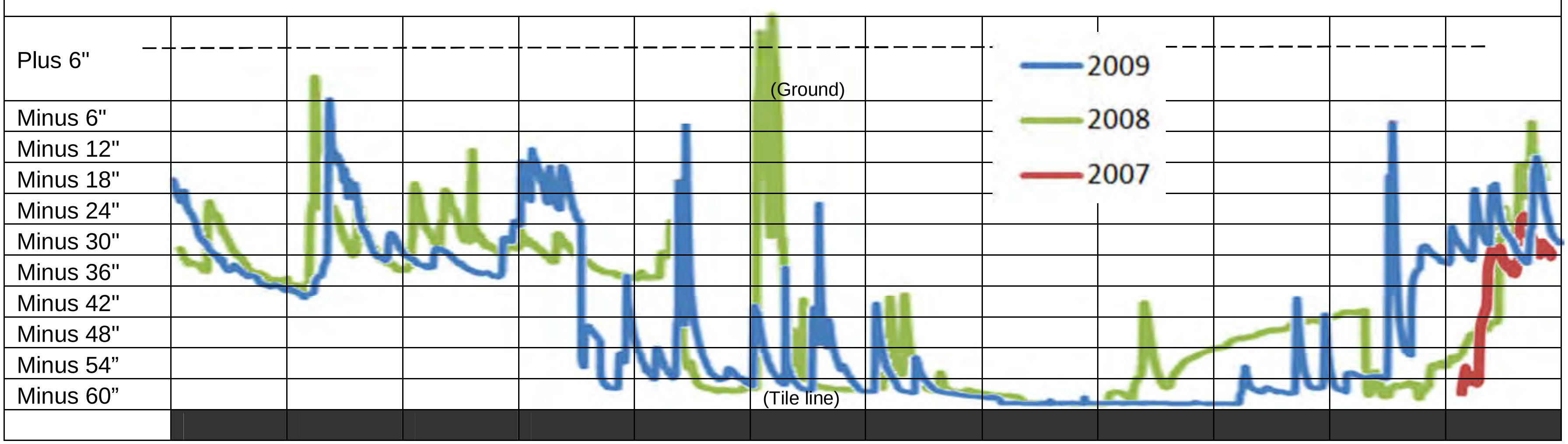


Figure 96. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Barry.

Crop:	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
2	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
3	***12"***	***12"***	***24"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
4	***12"***	***12"***	***24"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***

Crop:	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
2	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
3	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
4	***12"***	***12"***	***12"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***48"***	***12"***	***12"***
Drain Depth												

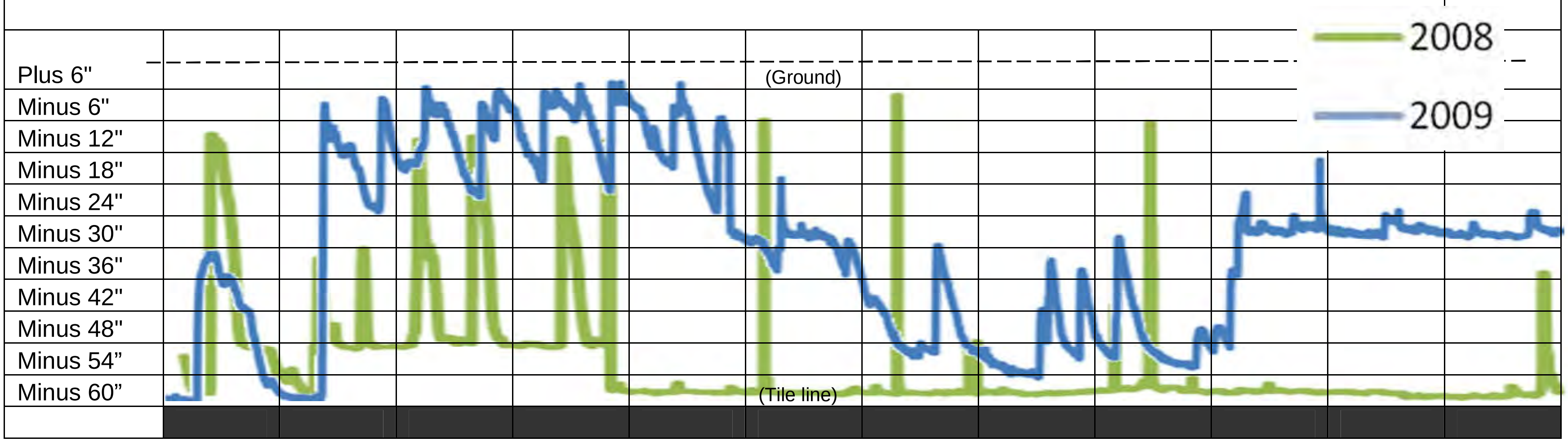
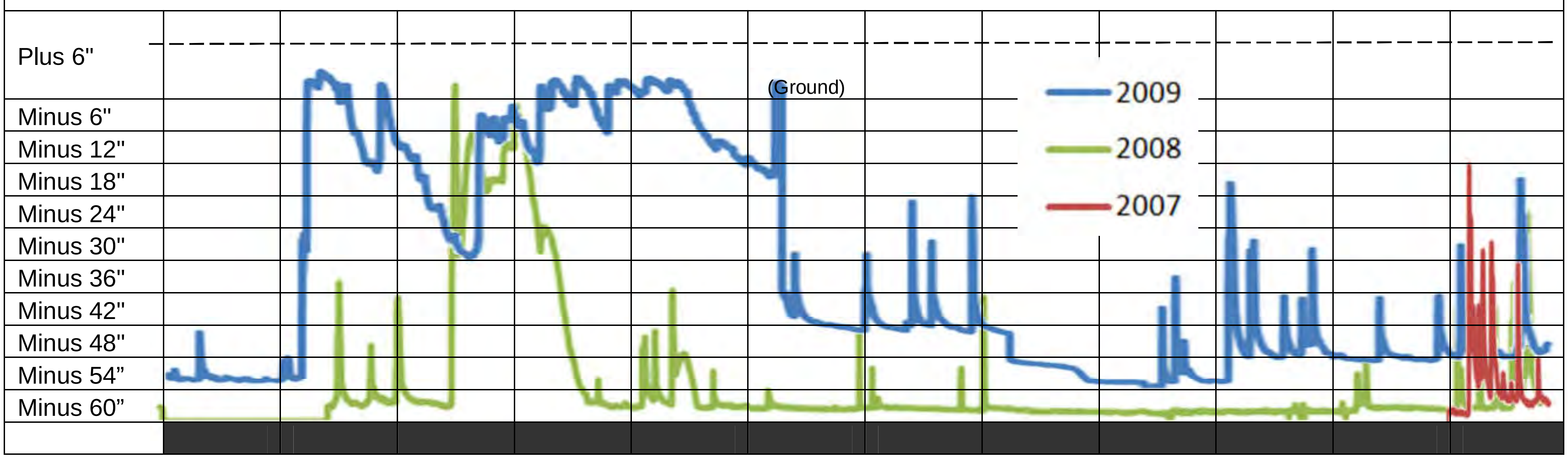


Figure 97. Recommended control plan for DWM by crop (stoplog depth from ground level in inches) – Enfield.

Crop:	Corn											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
2	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
3	***12”***	***12”***	***24”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
4	***12”***	***12”***	***24”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
Crop:	Soybeans											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Week												
1	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
2	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
3	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
4	***12”***	***12”***	***12”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***48”***	***12”***	***12”***
Drain Depth												



Illinois Cropping and Yield Data

Table 10a. Cropping and yield data for Site 1 (Hume N, Illinois).

		2006		2007		2008		2009	
Crop		Soybean		Corn		Soybean		Corn	
Variety									
Planting Date									
Row Spacing									
Tillage	**Conventional**	X		X		X		X	
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**			Fall				Fall	
	Actual N#s/acre	0		25		0		25	
Post-plant N application	**Date**			Spring				Spring	
	Actual N#s/acre	0		34		0		34	
Phosphorus	**Actual P#s/acre**	0		82		0		82	
Potash	**Actual K#s/acre**	60		108		60		108	
Herbicide	**oz/acre**								
Insecticide	**oz/acre**								
Harvest date		Sept 26		Oct 9		Oct 20		Nov 13	
Drainage	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield		58.6	57.2	184.9	187.5	48.0	48.0	179.8	174.6
Moisture		16.7	16.0	14.8	15.2	10.7	10.3	18.5	18.4
Comments (hail, drought, heat, wind, etc.)									

Table 10b. Cropping and yield data for Site 2 (Hume S, Illinois).

		2006		**2007**		**2008**		**2009**	
Crop		Soybean		Corn		Soybean		Corn	
Variety									
Planting Date									
Row Spacing									
Tillage	**Conventional**	X		X		X		X	
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**			Fall				Fall	
	Actual N#s/acre	0		25		0		25	
Post-plant N application	**Date**			Spring				Spring	
	Actual N#s/acre	0		34		0		34	
Phosphorus	**Actual P#s/acre**	0		82		0		82	
Potash	**Actual K#s/acre**	60		108		60		108	
Herbicide	**oz/acre**								
Insecticide	**oz/acre**								
Harvest date		Sept 27		Oct 1		Oct 19		Nov 11	
Drainage	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield		58.1	53.7	190.9	182.3	51.3	51.2	183.8	186.6
Moisture		14.4	15.8	16.9	17.2	11.4	10.8	17.7	17.8
Comments (hail, drought, heat, wind, etc.)									

Table 10c. Cropping and yield data for Site 3 (Barry, Illinois).

		2006		2007		2008		2009	
Crop		Corn		Corn		Corn		Corn	
Variety		?		?		?		?	
Planting Date		4/30		4/24		5/2		5/11	
Row Spacing		30”		30”		30”		30”	
Tillage	**Conventional**	X		X		X		X	
	Conservation	-		-		-		-	
	No Till	-		-		-		-	
Nitrogen	**Actual ”N”**	204		192		192		182	
Fall N application	**Date**	11/06		11/07		02/08		03/09	
	Actual N#s/acre	204		204		192		182	
Pre-plant N application	**Date**	11/05		11/07		02/08		03/09	
	Actual N#s/acre	-		-		-		-	
Post-plant N application	**Date**	-		-		-		-	
	Actual N#s/acre	-		-		-		-	
Phosphorus	**Actual P#s/acre**	150		150		150		none	
Potash	**Actual K#s/acre**	250		-		250		-	
Herbicide	**oz/acre**	?		?		?		?	
Insecticide	**oz/acre**	?		?		?		?	
Harvest date		Oct 20		Oct 16		Oct 29		Nov 30	
Drainage	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield		120.3	135.7			166.6	160.3		
Moisture		19.0	18.9			21.4	20.1		
Comments (hail, drought, heat, wind, etc.)		Wind		Wind		Rain		Rain	

Table 10d. Cropping and yield data for Site 4 (Enfield, Illinois).

		2006		**2007**		**2008**		**2009**	
Crop		Corn		Soybean		Corn		Soybean	
Variety								Pioneer 94Y60	
Planting Date									
Row Spacing									
Tillage	**Conventional**	X		X		X		X	
	Conservation								
	No Till								
Nitrogen									
Fall N application	**Date**								
	Actual N#s/acre								
Pre-plant N application	**Date**								
	Actual N#s/acre	In spray 30				In spray 30			
Post-plant N application	**Date**								
	Actual N#s/acre	160				160			
Phosphorus	**Actual P#s/acre**	259.911		0		369.7		0	
Potash	**Actual K#s/acre**	207.929		0		374.871		0	
Herbicide	**oz/acre**	Degree 48oz		Canopy 3oz		Degree 64oz		Prowl 2 pts	
Insecticide	**oz/acre**	Mustang Mix 3oz		0		Mustang Mix 3oz		0	
Harvest date				Oct 5		Nov 10		Nov 30	
Drainage	MD-managed drainage, CD-conventional drainage	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**	**CD**
Yield		192.6	197.7	60.8	50.5	186.2	194.8	53.5	54.7
Moisture		14.0	14.1	8.1	7.9	14.7	14.0	12.6	13.7
Comments (hail, drought, heat, wind, etc.)									

CIG RESULTS

Trying to quantify the information received from 20 sites requires in-depth review of precipitation information during the fallow season and the growing season, then comparison of that data to the long-term precipitation records. Drainage outflows and any increases in yields are contingent on the timing and volume of each rainfall event. Data collected by the collaborators indicate a reduction range of outflows and nutrients from 0 to 100%. However, under low precipitation and low tile flows, we can realize a lower volume but a higher percentage reduction. Conversely, just the opposite happens during higher precipitation events, which exhibit higher outflows but a lower percentage reduction between the conventional drainage plots vs. the managed demonstration plots.

Yield data from all sites were inconsistent because of the difficulty in quantifying the available water for plant growth and grain fill. Much of the available water was subject to timing of rainfall events and amount of rain.

Indiana Precipitation

Table 11a. Annual precipitation at the four research locations.

	30 yr avg	2007	Deviation	2008	Deviation	2009	Deviation
Francesville	37.40	46.16*	7.76*	43.56	6.16	41.97	4.57
Reynolds	38.70	27.78	-10.92	42.77	4.07	34.38	1.68
Wolcott	38.70	27.88	-10.82	45.03	6.33	43.35	4.65
Crawfordsville	39.80	34.43	-5.37	48.99	9.19	50.72	10.92

Precipitation prior to July 2007 was obtained from the Francesville Co-op.

Table 11b. Precipitation during the growing season at four locations in Indiana. The growing season went from May 1 to August 31.

	30 yr avg	2007	Deviation	2008	Deviation	2009	Deviation
Francesville	15.70	20.27*	4.57*	17.52	1.82	17.49	1.79
Reynolds	16.00	10.69	-5.31	15.36	-0.64	13.64	-2.36
Wolcott	16.00	9.42	-6.58	19.24	3.24	16.95	0.95
Crawfordsville	16.20	10.49	-5.71	21.37	5.17	24.37	8.17

Precipitation prior to July 2007 was obtained from the Francesville Co-op.

Indiana Drainage Outflow

Comments on Measurement Methods and Resulting Uncertainty

At the Francesville and Crawfordsville sites, flow was measured using SeaMetrics insertion electromagnetic flow meters. The flow meters were installed in U-shaped sections in the drainage pipe to create continuous full pipe flow conditions for which there was a constant flow area and velocity measured to determine flow. However, these flow meters required a minimum flow of 31 gallons per minute (Crawfordsville, Francesville south) or 18 gallons per minute (Francesville north) to record a non-zero flow. Therefore, although the meters were very effective at measuring high flow rates, much of the flow was not captured.

At Crawfordsville, flow was measured with a second method, using pressure transducers in a modified circular flume (Cooke et al., 2004). These devices were used for drain flow measurements at lower flow rates, and the resulting values are included in Tables 15a and 15b.

No secondary flow measurements were available for Francesville, so the flows shown in Tables 12a and 12b do not include periods when the flow was below 31 gallons per minute (south) or 18 gallons per minute (north). An additional problem at the Francesville site was due to the hydraulics of the tile system itself. Mains draining both the conventional and managed drainage areas join into a single main between the flow measurements and the ditch, and this single main often limited the flow capacity at high flows. During these high flow events, the free-draining field would begin draining while the water table rose in the managed field. Once the managed field water table reached the top of the structure outlet and water flowed over the boards, the greater head in this field filled the single main with flow from the managed field, which meant that the free-draining field stopped flowing for a time. As the flow from the managed field subsided, the free-draining field was able to drain again. The limited capacity of the main, and resulting variation in drain flow, would not be a significant problem except for the lack of low flow measurements due to the measurement device. Therefore, the overall results show higher flow in the managed field, although this is likely a result of the measurement shortcoming rather than an actual result.

At Wolcott and Reynolds, flow was measured with an area-velocity meter (Flo-Tote 3; www.marsh-mcbirney.com) which consisted of an electromagnetic velocity meter together with a level sensor to measure water level in the pipe. Since this device did not require a full pipe, measurements are available at both low and high flow. However, submergence problems at Reynolds still caused accuracy issues at low flows.

Table 12a. Francesville annual

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	0.12	2.28	180	No nitrate monitoring was done at Francesville.		
2008	2.49	2.07	-18			
2009	4.57	2.75	-50			

Table 12b. Francesville growing season

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	0.03	1.66	193	No nitrate monitoring was done at Francesville		
2008	0.63	0.52	-19			
2009	1.72	0.7	-84			

Note: The growing season was designated as May 1 through August 31.

Table 13a. Reynolds annual

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	6.4	9.2	36	15.19	19.85	27
2008	11.5	13.6	17	40.71	45.73	12
2009	11.1	10.1	-9	17.35	17.32	0

Table 13b. Reynolds growing season

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	0.9	0.1	-161	1.78	0.27	-147
2008	4.2	3.3	-22	18.14	12.81	-34
2009	2.9	4.2	36	4.74	6.77	35

Note: The growing season was designated as May 1 through August 31.

Table 14a. Wolcott annual

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	16.3	16.1	-1	39.54	35.24	-12
2008	11.2	13.2	17	38.04	37.54	-1
2009	13.0	13.6	4	17.09	16.88	-1

Table 14b. Wolcott growing season

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	1.02	0.97	-6	2.28	2.00	-13
2008	3.86	3.75	-3	19.82	17.65	-12
2009	4.54	3.86	-16	5.95	4.78	-22

Note: The growing season was designated as May 1 through August 31.

Table 15a. Crawfordsville annual

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	17.6	18.6	6	35.2	31.53	-11
2008	17.8	20.2	13	39.31	43.81	11
2009	19.3	14.8	-26	29.9	23.44	-24

Table 15b. Crawfordsville growing season

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	2.0	1.4	-36	4.08	2.50	-48
2008	6.4	4.9	-27	19.44	18.50	-5
2009	6.9	5.7	-20	10.76	8.90	-19

Note: The growing season was designated as May 1 through August 31.

Discussion of Effects of Drainage Water Management on Drain Flow

The annual and growing season total flow values provided in Tables 12 through 15 do not accurately show the effects of the managed drainage on flow or nitrate loss in these fields. This is due to at least two reasons: (1) the flow may differ significantly between the two fields at one site even without drainage water management, and a simple comparison does not capture this potential natural variation, and (2) the managed field was not always managed. In our case we had long periods with free drainage at both sites, because we wanted to resolve problems due to (1).

In order to truly compare the drain flow with and without managed drainage, we completed an additional analysis for sites 2, 3 and 4. This analysis used the statistically robust paired analysis method, which shows the effect of treatment by developing a relationship between the sites without treatment, and investigating the difference between the predicted flow based on that relationship and the observed flow. This analysis determined that there was a reduction in drain flow due to managed drainage at all three sites, ranging from 11.5 to 17.5% (Table 16). These results represent the best estimate of the effect of managed drainage, taking into account differences among fields at a site and also the varying drainage management periods.

Table 16. Results from paired-watershed analysis for three sites

Location	Drain flow reduction due to managed drainage (%)
Site 2 (Reynolds)	15.4
Site 3 (Wolcott)	11.5
Site 4 (Crawfordsville)	17.5

Discussion of Nitrate Loss Results

The nitrate loss reductions, also presented in Tables 12 to 15, have at least three limitations:

- Nitrate loss estimates use the same flow measurements which have limitations as discussed above.
- Loss estimates were based on periodic nitrate concentration measurements, measured approximately weekly at each field. Nitrate concentration ranged from less than 5 mg/L to more than 30 mg/L. The nitrate losses shown in this report were calculated by multiplying daily drain flow by nitrate concentrations averaged over periods of fairly consistent nitrate concentration.
- The paired analysis of nitrate loss, which would give a more complete analysis of the results of managed drainage on nitrate loss, is not yet available.

Indiana Crop Yields

Crop yield effects of managed drainage varied greatly from year to year, and across sites or different locations within the fields. Table 17 shows average annual yields for all four sites in the project, including two years of treatment before the project began at two of the sites. We also included yields from the Davis-Purdue Agricultural Center (DPAC) study, which was not part of the CIG project but which has two replications of managed vs. conventional drainage in quadrants of a 40-acre field. Yield effects were more often positive or neutral but were occasionally negative. Average annual yield differences ranged from *11% lower* in the managed drainage field to *13% higher* compared to the conventional drainage fields. As with flow and other data, caution should be used with direct comparisons of yields from the two fields at any site, because inherent yield differences may be present.

Table 17. Summary of yield data for all 4 sites, plus additional yield sites (DPAC)

	Drainage	Yield (pre-study) (bu/acre)		Yield during management (bu/acre)					Yield difference (M vs C) (%)				
Site Name		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2005**	**2006**	**2007**	**2008**	**2009**
Site 1 (Francesville)	**M**					**188***	**251***						
Site 1 (Francesville)	C					186	253						
Site 2 (Reynolds)	**M**	156	197	**171**	**185**	**186**	**202**	**175**	11.8	-11.1	1.1	0.0	6.7
Site 2 (Reynolds)	C	154	200	153	208	184	202	164					
Site 3 (Wolcott)	**M**		221	**43+**	**192**	**58+**	**169**	**57+**	4.9	2.7	7.4	-5.1	-5.0
Site 3 (Wolcott)	C		223	41+	187	54+	178	60+					
Site 4 (Crawfordsville)	**M**			**176**	**215**	**241**	**136**	**220**	0.6	3.9	4.3	5.4	10.6
Site 4 (Crawfordsville)	C			175	207	231	129	199					
Additional Yield Sites													
Site A1: DPAC-East	**M**	3 yrs		**174**	**172**	**107**	**192**	**193**	13.0	-1.7	0.0	0.0	2.7
Site A1: DPAC-East	C			154	175	107	192	188					
Site A2: DPAC-West	**M**	4 yrs		**150**	**167**	**110**	**196**	**194**	-3.8	7.7	5.8	3.7	4.3
Site A2: DPAC-West	C			156	155	104	189	186					

*At Site 1, in 2007 M is the North field, while in 2008 M is the South field. In both years, the North field had higher yield.

+ Soybeans grown at Site 3 in 2005, 2007, 2009

Yield data summarized by 6-inch contour

Site 1 (Francesville): 6-inch data not available

Site 2 (Reynolds)

Table 18a. Site 2 – Crop yield by elevation (6 in. contours) for conventional drainage

Reynolds, IN – Conventional							
elevation (ft)	2003	2004	2005	2006	2007	2008	2009
(694,694.5]	161.3	205.2	176.2	210.3	195.3	190.3	180.0
(694.5,695]	148.6	202.6	146.1	203.5	173.8	194.1	158.5
(695,695.5]	136.6	197.8	129.0	193.6	169.1	196.4	138.8
(695.5,696]	150.8	194.6	148.8	206.0	180.6	214.4	155.3
(696,696.5]	157.0	199.0	150.9	217.5	184.2	221.5	165.8
(696.5,697]	161.0	198.1	168.9	225.2	202.8	227.1	178.9
(697,697.5]	187.5	192.7	166.4	229.2	209.4	231.0	178.1
(697.5,698]	186.4	185.9	171.3	230.9	213.7	232.3	179.6
(698,698.5]	199.8	203.2	137.9	237.9	205.7	232.9	172.2
(698.5,699]	184.8	206.6	99.9	202.3	137.7	204.1	181.2

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Table 18b. Site 2 – Crop yield by elevation (6 in. contours) for managed drainage

Reynolds, IN – Managed							
elevation (ft)	2003	2004	2005	2006	2007	2008	2009
(694,694.5]	121.6	194.4	177.3	198.1	172.1	208.3	177.7
(694.5,695]	169.9	194.1	174.8	187.9	184.8	203.7	177.7
(695,695.5]	150.5	201.7	168.3	171.7	202.7	184.0	168.1
(695.5,696]	156.6	202.6	157.4	171.1	188.3	203.3	170.4
(696,696.5]	165.7	212.1	154.2	182.8	196.7	216.4	170.0
(696.5,697]	155.6	215.4	151.5	185.0	195.7	217.7	176.4
(697,697.5]	152.7	212.1	135.6	186.3	168.5	215.8	179.4
(697.5,698]	165.6	217.0	138.4	192.4	199.5	222.7	153.6
(698,698.5]	186.5	205.6	133.6	187.9	206.5	224.7	167.4
(698.5,699]	190.9	178.3	134.0	183.1	171.3	217.8	160.3
(699,699.3]	148.4	197.2	37.3	171.1	134.4	227.2	180.8

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Site 3 (Wolcott)

Table 19a. Site 3 – Crop yield by elevation (6 in. contours) for managed drainage of corn

Wolcott, IN – Conventional			
elevation (ft)	2004	2006	2008
(664.4,664.9]	220.3	185.4	172.4
(664.9,665.4]	225.8	188.6	185.8
(665.4,665.9]	226.3	188.7	185.0
(665.9,666.4]	226.5	192.9	181.1

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Table 19b. Site 3 – Crop yield by elevation (6 in. contours) for conventional drainage of corn

Wolcott, IN – Managed			
elevation (ft)	2004	2006	2008
(664.4,664.9]	217.9	180.8	161.1
(664.9,665.4]	228.8	194.2	173.1
(665.4,665.9]	223.9	196.8	177.3
(665.9,666.4]	220.3	193.4	171.2
(666.4,666.9]	219.6	195.2	168.9
(666.9,667.4]	224.0	196.4	164.4
(667.4,667.8]	215.4	187.8	161.8

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Table 19c. Crop yield by elevation (6 in. contours) for conventional drainage of soybeans

Wolcott – Soybeans – Conventional		
Elevation (ft)	2007	2009
(664.3,664.8]	52.3	61.9
(664.8,665.3]	55.1	60.3
(665.3,665.8]	54.2	58.9
(665.8,666.3]	57.2	58.4
(666.3,666.8]	32.5	48.3

Note: Shaded region indicates years in which drainage was managed.

Table 19d. Crop yield by elevation (6 in. contours) for managed drainage of soybeans

Wolcott – Soybeans – Managed		
Elevation (ft)	2007	2009
(664.3,664.8]	50.7	56.2
(664.8,665.3]	54.4	63.6
(665.3,665.8]	58.5	59.9
(665.8,666.3]	61.4	59.1
(666.3,666.8]	59.4	55.1
(666.8,667.3]	61.6	53.2
(667.3,667.8]	59.0	46.5
(667.8,667.81]	64.6	49.8

Note: Shaded region indicates years in which drainage was managed.

Site 4 (Crawfordsville)

Table 20a: Site 4 – Crop yield by elevation (6 in. contours) for conventional drainage

Crawfordsville, IN – Conventional					
elevation (ft)	2005	2006	2007	2008	2009
(846.2,846.7]	164.4	220.1	225.6	104.3	171.6
(846.7,847.2]	169.9	206.4	216.8	98.6	178.3
(847.2,847.7]	168.6	200.6	216.7	98.1	191.4
(847.7,848.2]	171.5	195.7	217.7	101.7	188.9
(848.2,848.7]	176.0	202.6	226.9	118.4	200.7
(848.7,849.2]	176.3	205.1	229.5	127.2	204.2
(849.2,849.7]	177.9	210.9	237.6	140.6	210.0
(849.7,850.2]	174.1	213.0	238.0	140.0	199.1
(850.2,850.7]	176.6	210.5	238.5	135.2	196.6
(850.7,851.2]	177.9	214.0	241.6	141.5	202.2
(851.2,851.7]	179.8	212.6	241.5	151.3	211.1
(851.7,852.2]	175.9	207.9	228.1	144.0	201.5
(852.2,852.7]	168.9	209.9	223.5	153.7	190.3
(852.7,853.2]	165.5	199.4	223.2	144.0	186.8
(853.2,853.7]	168.6	225.7	223.3	124.6	185.6
(853.7,854]	166.0	224.9	253.3	149.3	213.1

Note: Shaded region indicates years in which drainage was managed.

Table 20b. Site 4 – Crop yield by elevation (6 in. contours) for managed drainage

Crawfordsville, IN – Managed					
elevation (ft)	2005	2006	2007	2008	2009
(845.2,845.7]	174.4	198.8	228.5	124.1	185.9
(845.7,846.2]	169.3	201.5	233.7	126.1	225.6
(846.2,846.7]	172.9	217.0	234.0	124.8	196.7
(846.7,847.2]	174.9	218.7	247.1	138.2	211.4
(847.2,847.7]	178.6	223.2	241.2	144.5	220.6
(847.7,848.2]	180.1	217.7	242.3	144.5	237.5
(848.2,848.7]	180.0	217.1	243.9	143.2	240.9
(848.7,849.2]	177.6	215.8	238.3	138.0	228.5
(849.2,849.7]	177.7	204.7	246.7	128.7	212.4
(849.7,850.2]	176.5	203.9	252.4	152.9	205.4

Note: Shaded region indicates years in which drainage was managed.

Additional Site A1 for Yield Data (Davis East)

Table 21a: Additional Site A1- Crop yield by elevation (6 in. contours) for conventional drainage

Davis East – Conventional								
elevation (ft)	1996	1998	2002	2005	2006	2007	2008	2009
(962.4,962.9]	97.2	136.8	54.3	159.7	160.3	110.2	189.7	213.9
(962.9,963.4]	101.5	142.7	54.6	145.2	175.4	118.9	201.9	210.0
(963.4,963.9]	104.1	148.2	55.7	145.5	185.2	122.4	200.5	202.8
(963.9,964.4]	103.4	156.5	55.3	160.5	179.2	117.4	201.8	201.5
(964.4,964.9]	98.2	140.4	56.7	161.6	171.2	107.5	189.6	187.1
(964.9,965.4]	97.5	146.5	52.2	152.7	177.8	107.4	188.5	184.7
(965.4,965.9]	94.9	145.8	48.7	137.7	175.8	101.1	187.5	176.8
(965.9,966.4]	94.5	145.1	41.4	153.3	175.1	102.1	189.1	178.0
(966.4,966.9]	90.6	141.5	44.8	165.0	173.7	94.5	187.4	178.9
(966.9,967.4]	85.5	145.3	39.5	133.9	170.0	76.4	169.1	143.8

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Table 21b: Additional Site A1- Crop yield by elevation (6 in. contours) for managed drainage

Davis East – Managed								
elevation (ft)	1996	1998	2002	2005	2006	2007	2008	2009
(963.9,964.4]	100.5	148.8	26.4	171.3	175.8	126.4	184.5	224.0
(964.4,964.9]	99.2	146.6	40.2	169.9	175.0	121.7	201.8	214.1
(964.9,965.4]	104.6	150.6	43.7	174.9	179.8	120.9	193.5	211.3
(965.4,965.9]	102.1	147.6	46.7	171.9	177.7	117.1	191.7	204.3
(965.9,966.4]	99.9	143.2	47.0	174.2	166.0	106.5	194.1	191.8
(966.4,966.9]	97.6	140.8	47.8	174.1	170.1	101.0	190.3	186.3
(966.9,967.4]	93.3	138.4	50.8	181.9	167.9	89.0	189.2	171.4
(967.4,967.9]	90.5	138.1	43.1	174.6	167.4	82.7	181.3	163.9
(967.9,968.4]	89.6	141.1	50.8	169.3	171.1	87.2	192.6	159.6
(968.4,968.8]	90.1	144.4	55.6	173.0	171.1	81.8	194.1	155.8

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Additional Site A2 for Yield Data (Davis West)

Table 21c: Additional Site A2- Crop yield by elevation (6 in. contours) for conventional drainage

Davis West – Conventional									
elevation (ft)	1996	1998	2001	2003	2005	2006	2007	2008	2009
(961.8,962.3]	40.7	145.6	182.2	142.9	111.2	121.0	123.5	196.6	190.6
(962.3,962.8]	71.2	139.1	183.8	120.7	137.1	140.2	119.2	179.7	194.0
(962.8,963.3]	85.5	135.9	175.8	115.7	159.4	149.5	120.2	181.1	190.0
(963.3,963.8]	95.1	154.1	181.8	135.6	158.9	160.2	116.2	193.4	193.8
(963.8,964.3]	93.9	146.5	179.4	132.5	148.8	153.6	108.3	195.5	203.3
(964.3,964.8]	93.8	141.6	174.8	129.1	160.0	168.3	110.9	200.1	203.5
(964.8,965.3]	93.1	140.0	177.9	125.4	159.8	170.4	104.1	195.8	188.2
(965.3,965.8]	87.2	127.2	171.5	109.5	156.4	144.4	90.6	179.7	170.4
(965.8,966.3]	87.1	124.5	168.9	106.9	155.8	142.8	86.4	176.9	164.2
(966.3,966.8]	87.3	133.2	170.3	121.5	158.3	146.2	93.2	186.4	169.8
(966.8,967.3]	89.1	135.4	168.9	130.0	161.5	157.0	92.7	190.8	173.9
(967.3,967.8]	90.0	133.4	169.9	126.1	155.4	160.0	87.4	187.2	167.5
(967.8,968.3]	90.1	138.4	168.4	131.6	161.8	160.4	97.2	196.9	177.5
(968.3,968.5]	91.3	145.9	168.0	137.8	160.8	161.5	105.9	193.7	172.0

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Table 21d: Additional Site A2- Crop yield by elevation (6 in. contours) for managed drainage

Davis West – Managed									
elevation (ft)	1996	1998	2001	2003	2005	2006	2007	2008	2009
(961.3,961.8]	70.0	141.7	167.0	135.9	153.2	162.3	117.7	191.7	208.2
(961.8,962.3]	78.9	146.6	172.6	134.8	152.4	162.5	111.2	192.7	206.9
(962.3,962.8]	71.8	155.9	180.3	136.0	152.2	167.6	112.1	195.6	201.5
(962.8,963.3]	81.0	150.7	178.1	130.0	147.9	166.7	107.8	196.2	189.2
(963.3,963.8]	87.3	154.0	176.5	138.0	144.2	171.5	109.7	199.8	188.8
(963.8,964.3]	90.8	147.9	180.0	143.7	151.4	167.4	106.9	199.4	182.3
(964.3,964.8]	94.6	145.6	174.1	143.9	150.5	169.1	103.6	187.1	173.0
(964.8,965.3]	99.5	156.7	188.6	158.4	169.7	174.9	109.9	190.9	175.1

Note: Shaded region indicates years in which drainage was managed. (Previous years included to help in interpretation of yield effects).

Iowa Precipitation

Table 22a. Hamilton CO precipitation (in)

	10yr Av	2007	Deviation	2008	Deviation	2009	Deviation
January	0.9	0.17	-0.7	0.12	-0.7	0.15	-0.7
February	1.2	1.29	0.1	0.63	-0.6	0.49	-0.7
March	1.8	2.08	0.3	1.86	0.1	3.86	2.1
April	3.7	7.63	4.0	5.02	1.4	3.41	-0.2
May	5.0	5.39	0.4	6.40	1.4	4.04	-0.9
June	5.7	2.94	-2.7	10.03	4.4	5.66	0.0
July	4.7	4.08	-0.6	6.70	2.0	2.52	-2.2
August	4.4	9.12	4.7	2.21	-2.2	5.18	0.8
September	2.9	2.12	-0.7	2.47	-0.4	2.47	-0.4
October	2.0	5.54	3.6	3.64	1.7	6.04	4.1
November	1.6	0.05	-1.5	2.05	0.5	0.47	-1.1
December	1.0	0.90	-0.1	0.28	-0.7	0.61	-0.4
Sum	34.6	41.3	6.7	41.4	6.8	34.9	0.3

Jan.-Mar. 2007 Precip from Webster City Weather station.

Apr.-Dec. from onsite weather station.

Table 22b. Story City precipitation (in)

Month	40yr Av	2006	Deviation	2007	Deviation	2008	Deviation	2009	Deviation
January	0.73	0.83	0.10	0.03	-0.70	0.03	-0.70	0.10	-0.63
February	0.86	0.01	-0.85	0.70	-0.16	0.64	-0.22	0.21	-0.65
March	2.06	2.48	0.42	1.96	-0.10	2.97	0.91	4.01	1.95
April	3.44	3.57	0.13	5.90	2.46	4.80	1.36	4.95	1.51
May	4.36	1.74	-2.62	5.34	0.98	8.49	4.13	5.21	0.85
June	5.10	0.86	-4.24	1.56	-3.54	5.81	0.71	3.56	-1.54
July	4.00	5.05	1.05	4.23	0.23	7.88	3.88	2.56	-1.44
August	4.10	6.07	1.97	7.81	3.71	3.25	-0.85	3.75	-0.35
September	3.13	7.51	4.38	1.83	-1.30	2.08	-1.05	0.00	-3.13
October	2.39	1.99	-0.40	5.02	2.63	3.90	1.51		
November	1.66	1.75	0.09	0.74	-0.92	2.25	0.59		
December	0.96	2.61	1.65	0.25	-0.71	0.41	-0.55		
Year	32.79	34.47	1.68	35.37	2.58	42.51	9.72	24.35	-3.43

Table 22c. Crawfordsville precipitation (in)

	10yr Av	2007	Deviation	2008	Deviation	2009	Deviation
January	1.55	0.87	-0.68	0.32	-1.23	0.48	-1.07
February	1.81	1.76	-0.05	0.10	-1.71	0.97	-0.84
March	2.32	3.64	1.32	0.92	-1.40	4.25	1.93
April	3.68	4.99	1.32	5.34	1.67	2.26	-1.42
May	5.07	3.35	-1.72	5.36	0.29	5.95	0.88
June	3.77	7.51	3.74	6.26	2.49	8.61	4.84
July	2.90	4.20	1.30	3.34	0.44	4.84	1.94
August	4.18	7.52	3.35	3.80	-0.38	9.78	5.61
September	3.03	2.02	-1.01	8.16	5.13	1.38	-1.65
October	3.04	3.85	0.81	2.36	-0.68	7.17	4.13
November	1.62	0.60	-1.02	0.19	-1.43		
December	1.67						
Year	34.63	40.31	5.69	36.15	1.52	45.69	11.06

Table 22d. Pekin precipitation (in)

	10yr Av	2005	Deviation	2006	Deviation	2007	Deviation	2008	Deviation	2009	Deviation
January	1.12	2.64	1.52	2.33	1.21	0.15	-0.97	0.32	-0.8	0.43	-0.69
February	1.13	1.41	0.28	0.34	-0.79	1.02	-0.11	1.59	0.46	2.01	0.88
March	2.38	0.69	-1.69	3.88	1.50	3.24	0.86	1.76	-0.62	5.08	2.70
April	3.45	2.95	-0.50	2.99	-0.46	4.45	1.00	4.98	1.53	3.14	-0.31
May	4.49	1.49	-3.00	1.22	-3.27	4.13	-0.36	0.42	-4.07	3.30	-1.19
June	4.18	2.94	-1.24	1.48	-2.70	6.10	1.92	8.04	3.86	5.29	1.11
July	4.34	2.21	-2.13	3.16	-1.18	4.81	0.47	6.82	2.48	2.19	-2.15
August	4.15	2.64	-1.51	0.77	-3.38	9.51	5.36	2.82	-1.33	10.08	5.93
September	3.91	3.26	-0.65	0.29	-3.62	5.87	1.96	4.71	0.80	0.00	-3.91
October	2.82	1.66	-1.16	2.23	-0.59	3.26	0.44	1.19	-1.63	4.37	1.55
November	2.49	1.92	-0.57	1.92	-0.57	0.20	-2.29	1.57	-0.92	0.11	-2.38
December	1.46	1.11	-0.35	2.23	0.77	1.64	0.18	0.59	-0.87		
Year	35.92	24.93	-10.99	22.84	-13.08	44.38	8.46	34.81	-1.11	36.00	1.54

Iowa Drainage Outflows

Table 23a. 2007 Hamilton County*

Month	Monthly Flow (in)			Monthly Nitrate Concentration		
	Conventional	Managed	% Reduction	Conventional	Managed	
January						
February						
March						
April	No sensor installed	No sensor installed		9.6	12.9	
May	No sensor installed	2.12		14.2	14.6	
June	No sensor installed	0.34		17.2	20.3	
July	No sensor installed	0		12.8	17.8	
August	3.24	2.43		7.5	6.8	
September	0.03	0		7.7	9.7	
October	8.16	6.09				
November	0	0				
December	0	No sensor – rodent damage				
Annual	11.43	10.98		11.50	13.7	

Note: both areas conventional drainage

Table 23b. 2008 Hamilton County

Month	Monthly Flow (in)			Monthly Nitrate Concentration		
	Conventional	Managed	% Reduction	Conventional	Managed	
January	No sensor installed	No sensor installed				
February	No sensor installed	No sensor installed				
March	No sensor installed	No sensor installed				
April	0.2	1.9	-848%	5.6	8.2	
May	2.7	2.0	24%	5.7	8.3	
June	1.3	5.6	-338%	12.4	16.6	
July	5.5	0.8	85%	11.8	15.7	
August	1.1	0.0	100%	8.5	15.0	
September	0.0	0.0	100%	5.8		
October	0.0	0.0	96%	8.5	11.4	
November	0.30	0.6	-95%	9.2	12.3	
December	No sensor installed	No sensor installed				
Annual	11.1	11.0	1%	8.4	12.5	

Table 23c. 2009 Hamilton County

Month	Monthly Flow (in)			Monthly Nitrate Concentration		
	Conventional	Managed	% Reduction	Conventional	Managed	% Reduction
January	No sensor installed	No sensor installed				
February	No sensor installed	No sensor installed				
March	0.79	0.00	100%	7.9	8.6	
April	0.94	1.13	-20%	13.0	7.5	
May	0.41	1.73	-325%	16.4	11.7	
June	0.73	1.12	-54%		13.7	
July	0.06	0.02	59%		13.0	
August	0.01	0.00	100%			
September	0.00	0.00	0%			
October	0.62	1.55	-150%	12.8	8.9	
November	0.37	0.58	-60%	9.6	6.3	
December	No sensor installed	No sensor installed		9.8	5.7	
Annual	3.93	6.15	-56%	11.6	9.4	

Table 23d. 2006 Story City, flow averaged for all plots, N loss for 140# treatment only

Month	Monthly Flow (in)			Monthly Nitrate Loss (#-N/ac)		
	Conventional	Managed	% Reduction	Conventional	Managed	% Reduction
January	0.00	0.00				
February	0.00	0.00				
March	0.12	0.05	57%			
April	1.31	0.88	33%	4.47	3.57	20%
May	1.44	1.17	19%	5.03	4.26	15%
June	0.22	0.17	21%	0.51	1.03	-104%
July	0.00	0.00		0.00	0.00	
August	0.00	0.00		0.00	0.00	
September	2.25	1.61	28%	5.25	1.93	63%
October	0.98	1.08	-11%	2.55	3.32	-30%
November	0.76	0.77	-2%	1.79	2.31	-29%
December	1.27	0.76	41%	2.11	1.16	45%
Annual	8.34	6.50	22%	21.72	17.58	19%

Table 23e. 2007 Story City, flow averaged for all plots, N loss for 140# treatment only

Month	Monthly Flow (in)			Monthly Nitrate Loss (#-N/ac)		
	Conventional	Managed	% Reduction	Conventional	Managed	% Reduction
January	1.75	0.90	49%	5.49	2.06	62%
February	0.38	0.19	49%	0.63	0.45	29%
March	2.51	1.13	55%	6.00	2.06	66%
April	2.87	2.15	25%	7.07	4.24	40%
May	3.19	2.51	21%	8.05	5.11	36%
June	1.64	1.47	11%	3.61	3.24	10%
July	0.06	0.08	-39%	0.08	0.34	-322%
August	0.37	0.16	55%	0.45	0.29	37%
September	0.57	0.35	39%	0.80	0.63	21%
October	3.35	2.46	27%	6.15	4.45	28%
November	0.44	0.21	51%	0.41	0.53	-28%
December	0.20	0.06	70%	0.09	0.18	-90%
Annual	17.31	11.66	33%	38.84	23.57	39%

Table 23f. 2008 Story City, flow averaged for all plots, N loss for 140# treatment only

Month	Monthly Flow (in)			Monthly Nitrate Loss (#-N/ac)		
	Conventional	Managed	% Reduction	Conventional	Managed	% Reduction
January	0.10	0.03	75%	0.10	0.09	17%
February	0.04	0.02	61%	0.07	0.09	-25%
March	0.95	0.37	61%	1.79	0.77	57%
April	3.65	3.14	14%	9.57	6.74	30%
May	2.29	2.13	7%	6.42	5.51	14%
June	3.36	2.67	21%	12.44	10.19	18%
July	0.77	0.53	31%	1.71	1.84	-7%
August	0.20	0.13	36%	0.39	0.61	-57%
September	0.03	0.01	57%	0.06	0.12	-114%
October	1.45	1.07	26%	2.97	3.38	-14%
November	1.94	1.76	9%	3.34	3.69	-11%
December	0.55	0.20	64%	0.78	0.46	41%
Annual	15.33	12.04	21%	39.64	33.48	16%

Table 23g. 2009 Story City, flow averaged for all plots, N loss for 140# treatment only

Month	Monthly Flow (in)			Monthly Nitrate Loss (#-N/ac)		
	Conventional	Managed	% Reduction	Conventional	Managed	% Reduction
January	0.29	0.13	57%	0.50	0.36	28%
February	0.33	0.08	74%	0.51	0.19	62%
March	1.39	0.96	31%	1.99	0.62	69%
April	2.55	2.30	10%	3.81	3.45	9%
May	1.71	1.79	-5%	2.28	2.94	-29%
June	1.72	1.64	4%	2.50	2.56	-2%
July	0.74	0.64	14%	0.92	1.07	-17%
August	0.02	0.02	8%	0.01	0.05	-443%
September	0.00	0.01		0.00	0.03	
October						
November						
December						
Annual	8.74	7.57	13%	12.50	11.26	10%

Table 23h. 2007 Crawfordsville, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February										
March										
April	0.02	0.02	32%	0.01	-37%	0.06	0.08	-33%	0.03	50%
May	1.19	2.22	-86%	1.27	-7%	3.22	6.50	-102%	4.03	-25%
June	3.86	2.70	30%	3.30	15%	7.10	5.95	16%	4.79	33%
July	0.09	0.07	21%	0.06	31%					
August	1.72	0.83	52%	1.25	27%	10.50	2.30	78%	8.19	22%
September	0.00	0.02		0.01						
October	1.60	1.17	27%	1.23	23%					
November	0.02	0.01	34%	0.02	-2%					
December	1.63	0.00	100%	0.00	100%					
Annual	10.14	7.05	30%	7.16	29%	20.87	14.86	29%	17.04	18%

Table 23i. 2008 Crawfordsville, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February	0.02	0.00	100%	0.00	100%					
March	0.00	0.55		0.00		0.01	0.04	-300%	0.02	-100%
April	2.36	3.05	-29%	1.39	41%	5.70	2.60	54%	4.07	29%
May	2.68	2.30	14%	1.16	57%	6.58	2.98	55%	2.37	64%
June	3.73	1.30	65%	1.20	68%	10.24	0.62	94%	4.60	55%
July	0.68	0.01	100%	0.01	100%					
August	0.00	0.00		0.88						
September	2.25	1.93	14%	0.95	58%					
October	0.22	0.00	100%	0.02	90%					
November	0.12	0.00	100%	0.00	100%					
December										
Annual	12.07	9.15	24%	5.60	54%	22.53	6.23	72%	11.06	51%

Table 23j. 2009 Crawfordsville, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January	0.31	0.00	100%	0.18	43%					
February	0.20	0.02	90%	0.02	89%					
March	1.96	0.88	55%	1.93	2%	4.50	0.65	86%	5.45	-21%
April	1.80	1.48	18%	0.43	76%	0.28	0.63	-125%		100%
May	3.43	4.04	18%	1.87	45%	9.75	13.01	-33%	7.82	20%
June	5.40	2.48	54%	3.41	37%					
July	1.89	0.85	55%	1.26	34%					
August	3.06	1.59	48%	1.40	54%					
September	0.00	0.06		0.05						
October	4.95	2.52	49%	2.52	49%					
November	0.10	0.03	70%	0.10	0%					
December										
Annual	23.11	13.94	40%	13.16	43%	14.53	14.29	2%	13.27	9%

Table 23k. 2005 Pekin, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage*.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February										
March										
April	2.18	0.87	60%	0.22	90%					
May	0.36	0.23	36%	0.02	95%					
June	0.91	0.28	69%	0.03	97%					
July	0.13	0.01	92%	0.01	95%					
August										
September										
October										
November										
December										
Annual	3.58	1.39	61%	0.27	93%					

a. Pseudo-shallow drainage: control structure set at 2 ft below surface year-round.

Table 23l. 2006 Pekin, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage*.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February										
March	2.10	0.17	92%	0.14	93%					
April	0.98	0.72	27%	0.05	95%	0.74	0.40	98%	0.03	96%
May	0.37	0.24	35%	0.01	96%	0.48	0.34	29%	0.02	95%
June	0.02	0.03	-11%	0.00	91%					
July										
August										
September										
October										
November										
December										
Annual	3.47	1.15	67%	0.20	94%	1.22	0.74	39%	0.05	96%

Pseudo-shallow drainage: control structure set at 2 ft below surface year-round.

Table 23m. 2007 Pekin, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage*.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February										
March	1.19	0.02	98%	0.13	89%	1.59	0.03	98%	0.23	86%
April	3.85	2.86	26%	1.32	66%	11.48	7.02	39%	5.44	53%
May	2.50	1.90	24%	0.77	69%	6.30	5.34	15%	2.26	64%
June	4.05	0.79	81%	1.01	75%	7.82	0.78	90%	1.23	84%
July	1.61	0.18	89%	0.25	84%	9.03	2.33	74%	3.75	58%
August	2.23	0.80	64%	0.85	62%	5.06	1.15	77%	2.36	53%
September	0.17	0.02	91%	0.00	100%	2.28	0.00	100%	0.56	75%
October	2.61	2.02	22%	0.75	71%					
November	0.13	0.03	80%	0.01	95%					
December	0.04	0.00	100%	0.01	66%					
Annual	18.69	8.65	54%	5.15	72%	41.97	16.62	60%	15.83	62%

Pseudo-shallow drainage: control structure set at 2 ft below surface.

Table 23n. 2008 Pekin, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage*.

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February										
March	2.12	0.07	96%	0.20	90%	2.15	0.05	98%	0.19	91%
April	2.86	1.19	59%	0.27	91%	5.97	2.04	66%	0.43	93%
May	1.34	1.46	-9%	0.22	83%	2.75	2.61	5%	0.18	93%
June	6.44	2.63	59%	2.01	69%	9.00	3.16	65%	1.87	79%
July	2.64	0.56	79%	0.63	76%	8.08	2.13	74%	1.64	80%
August	0.34	0.00	100%	0.01	96%	2.47	0.66	73%	0.64	74%
September	0.04	0.15	-276%	0.00	94%	0.17	0.02	88%	0.00	100%
October	0.01	0.08	-501%	0.00	88%	0.14	0.03	79%		
November	0.60	0.08	86%	0.00	100%					
December	0.21	0.03	98%	0.00	100%					
Annual	16.60	6.25	62%	3.34	80%	28.58	10.65	63%	5.00	83%

Pseudo-shallow drainage: control structure set at 2 ft below surface.

Table 23o. 2009 Pekin, flow and nitrate loss in drainage treatments: CD-conventional drainage, MD-managed drainage, SD-shallow drainage*,.**

Month	Monthly Flow (in)					Monthly Nitrate Loss (#-N/ac)				
	CD	MD	% Reduction	SD	% Reduction	CD	MD	% Reduction	SD	% Reduction
January										
February										
March	1.56	0.00	100%	0.00	100%					
April	1.55	0.00	100%	0.02	99%	1.53	0.00	100%	0.00	100%
May	3.89	2.90	26%	0.94	76%	5.83	1.39	76%	1.85	68%
June	7.31	2.57	65%	2.51	66%	2.77	0.78	72%	0.47	83%
July	0.21	0.00	100%	0.01	95%					
August	2.93	1.48	49%	1.60	45%					
September	0.30	0.00	100%	0.03	91%					
October	1.44	1.30	10%	0.23	84%					
November	4.98	3.82	23%	1.34	73%					
December	1.12	1.58	-41%	0.26	77%					
Annual	25.29	13.65	46%	6.95	73%	10.13	2.18	78%	2.32	77%

*Some water samples for 2nd half of 2009 still being analyzed:

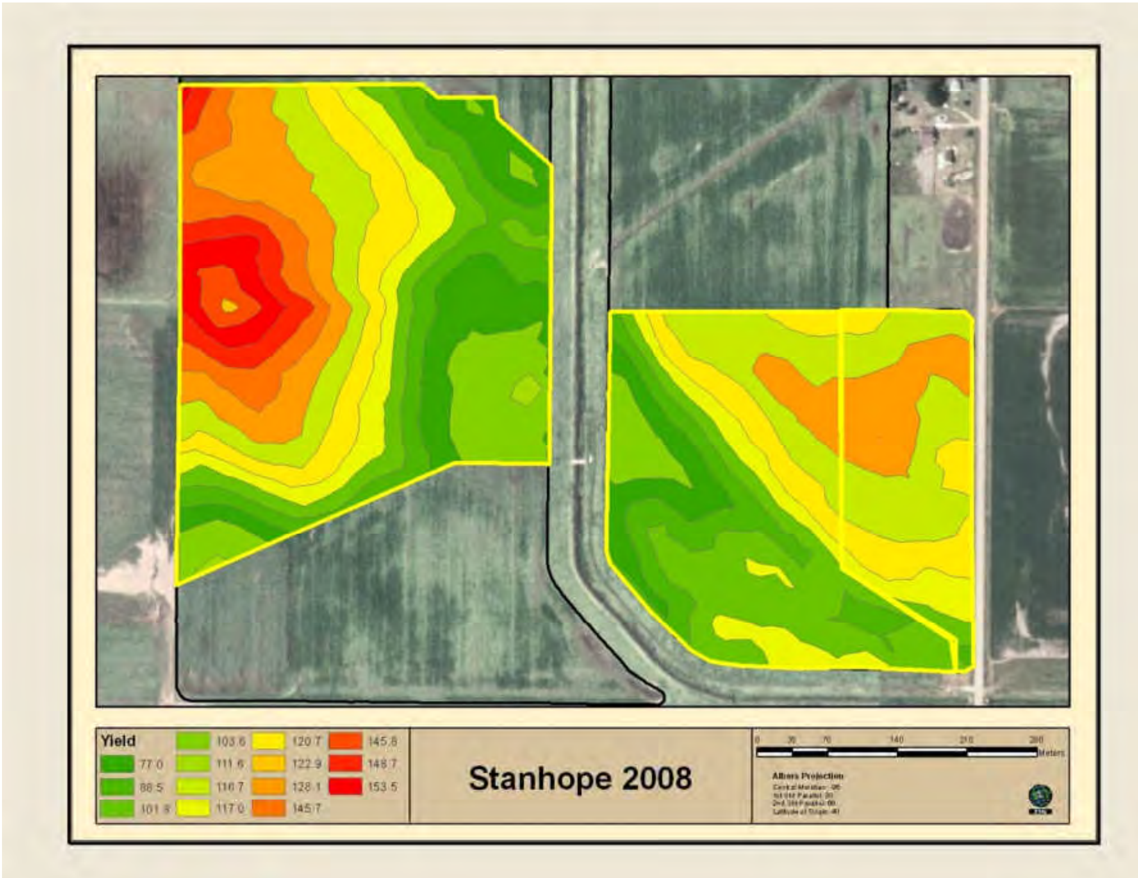
** Pseudo-shallow drainage: control structure set at 2 ft below surface year-round.

Iowa Crop Yields

Table 24a. 2008 – Stanhope corn yields from farmer's yield monitor on 8" intervals.

DWM elevation (ft)	yield (bu/ac)	CNV elevation (ft)	yield (bu/ac)
east side			
1089.90	37.7	1087.93	126.9
1090.55	78.9	1088.58	78.5
1091.21	112.7	1089.24	72.3
1091.86	109.0	1089.90	81.8
1092.52	105.1	1090.55	101.7
west side		1091.21	113.1
1088.58	82.8	1091.86	114.1
1089.24	81.7	1092.52	111.8
1089.90	80.2	1093.18	139.7
1090.55	90.3	1093.83	167.5
1091.21	112.3	1094.49	177.3
1091.86	129.8	1095.14	183.8
		1095.80	192.5
		1096.46	183.1

Figure 98. 2008 Stanhope corn yield averaged by 8" elevation increments.



Two fields outlined on the east side are in DWM with two separate control gates. Field on west side is the conventional drainage field.

The average slope at Story City is about 0.8%, thus the maximum zone of influence of the control gate is about 300 ft. Yields were measured by weight, corrected for moisture, with a plot combine. Results shown below are for the medium (140#/ac) N treatment only.

Table 24b. Story City – 2006, corn.

	DWM			CD	
distance (ft)	elev (ft)	yield (bu/ac)	distance (ft)	elev (ft)	yield (bu/ac)
3.8	1008.8	201.7	3.8	1008.8	169.4
11.3	1008.8	174.2	11.3	1008.9	160.3
18.8	1008.8	154.1	18.8	1009.0	161.4
26.3	1008.8	159.0	26.3	1009.0	148.3
33.9	1008.9	172.6	33.8	1009.1	152.2
41.4	1008.9	195.7	41.3	1009.1	167.8
48.9	1008.9	162.8	48.8	1009.1	162.4
56.4	1009.0	169.6	56.3	1009.1	153.2
64.0	1009.0	159.6	63.8	1009.1	160.8
70.2	1009.1	169.6	70.0	1009.1	161.6
75.2	1009.1	181.7	75.0	1009.1	167.2
103.3	1009.3	172.6	103.0	1009.3	163.0
154.0	1010.0	177.0	152.5	1009.6	166.5
204.7	1010.5	177.1	202.3	1009.8	164.3
254.8	1011.1	172.0	252.8	1010.1	178.8
304.0	1011.6	165.7	302.0	1010.5	162.3
353.7	1012.1	172.2	351.5	1011.0	174.1
414.9	1012.8	179.6	401.3	1011.6	179.6
467.5	1013.4	174.1	450.8	1012.2	162.0

Table 24c. Story City – 2007 soybean.

	DWM			CD	
distance (ft)	elev (ft)	yield (bu/ac)	distance (ft)	elev (ft)	yield (bu/ac)
24.5	1008.8	67.2	24	1009.0	49.7
74.5	1009.1	65.9	72.75	1009.1	54.1
124.5	1009.6	64.2	123	1009.4	50.3
173.5	1010.2	66.2	173.75	1009.7	53.2
223.5	1010.7	61.8	223.75	1009.9	51.3
274.5	1011.2	63.0	273.25	1010.2	61.0
324.5	1011.8	62.5	323.25	1010.7	62.2
373.5	1012.4	64.3	373	1011.3	63.5
423.5	1012.9	62.9	423	1011.9	61.5
482.5	1013.5	62.3	486.75	1012.6	64.6

Table 24d. Story City – 2008, corn.

	DWM			CD	
distance (ft)	elev (ft)	yield (bu/ac)	distance (ft)	elev (ft)	yield (bu/ac)
3.8	1008.8	211.9	3.8	1008.8	173.2
11.3	1008.8	181.4	11.3	1008.9	207.4
18.8	1008.8	217.0	18.8	1009.0	212.6
26.3	1008.8	168.5	26.3	1009.0	201.6
33.9	1008.9	178.3	33.8	1009.1	204.4
41.4	1008.9	187.1	41.3	1009.1	220.8
48.9	1008.9	167.2	48.8	1009.1	193.9
56.4	1009.0	157.5	56.3	1009.1	204.7
64.0	1009.0	150.7	63.8	1009.1	202.3
71.5	1009.1	155.5	71.3	1009.1	191.1
77.8	1009.1	177.3	77.5	1009.1	203.3
104.8	1009.3	207.7	105.0	1009.3	211.3
156.0	1010.0	196.7	155.3	1009.6	212.8
207.7	1010.5	220.6	205.5	1009.8	208.2
257.8	1011.1	219.0	255.8	1010.1	209.1
308.5	1011.6	205.2	306.0	1010.5	214.5
358.7	1012.1	210.8	355.8	1011.0	205.9
407.3	1012.8	205.7	405.3	1011.6	206.4
456.5	1013.4	213.5	455.0	1012.2	204.6

Table 24e. Story City – 2009, soybean.

	DWM			CD	
distance (ft)	elev (ft)	yield (bu/ac)	distance (ft)	elev (ft)	yield (bu/ac)
24.0	1008.8	58.4	23.75	1009.0	62.2
73.0	1009.1	62.3	71.75	1009.1	57.4
124.5	1009.6	59.8	120.25	1009.4	54.0
176.0	1010.2	55.2	168.75	1009.7	57.9
225.5	1010.7	59.0	218.75	1009.9	63.4
274.5	1011.2	58.4	269	1010.2	57.6
324.5	1011.8	64.1	318.75	1010.7	64.5
375.5	1012.4	58.4	369	1011.3	61.4
426.0	1012.9	60.6	418.75	1011.9	61.2
484.0	1013.5	63.5	476	1012.6	55.3

Table 24f. Crawfordsville – 2007-2009, corn & soybean.

	Conventional		Managed		Shallow		No drainage	
Year	Corn	Soybean	Corn	Soybean	Corn	Soybean	Corn	Soybean
	bu/ac							
2007	178.5	57.8	170.6	55.9	177.3	51.4	167.0	46.7
2008	171.6	46.9	168.2	47.6	175.7	45.2	176.9	47.7
2009	169.9	67.4	152.5	63.4	161.9	62.6	138.9	45.7

Table 24g. Pekin – 2005-2009, corn & soybean.

	Conventional		Managed		Pseudo-Shallow*	
Year	Corn	Soybean	Corn	Soybean	Corn	Soybean
	bu/ac					
2005	136.4	38.3	135.0	43.5	126.8	37.1
2006**	/	/	/	/	/	/
2007	139.3	43.7	141.7	45.7	127.7	45.3
2008	228.1	41.8	223.4	44.0	218.6	44.4
2009***	/	57.7	/	55.3	/	53.6

*Pseudo-shallow drainage: control structure set at 2 ft below surface;
** The 2006 growing season was plagued with planting and fertilizing issues and the yield data is not included;
*** No corn yield data for individual plots in 2009 but the average corn yield was estimated to be 148 bu/acre.

Ohio Precipitation-

Data not provided

Ohio Drainage Outflows-

Data not provided

Ohio Crop Yields

Table 25. Crop and yield summary of Ohio CIG regional sites in 2008, full zone means.

Site Name	County	Crop	Management	Zone Area (acre)	Average Yield over Full Zone (bu/ac)	Yield Increase (bu/ac)	Standard Error
Napoleon	Henry	Popcorn	Managed Drainage	38.3	57.96*	1.29	0.14
			Conventional Drainage	32.8	59.25*		0.16
Lakeview	Auglaize	Soybean	Managed Drainage	19.8	43.6*	0.8	11.16
			Conventional Drainage	30.6	42.8*		12.76
Dunkirk	Hardin	Corn	Managed Drainage	15.6	123.4*	19.8	0.50
			Conventional Drainage	13.0	103.6*		0.53
Defiance	Defiance	Soybean	Managed Drainage	19	29.4	1.0	0.58
			Conventional Drainage	20	28.4		0.64

*- Means statistically significant using the two sample *t*-test at error rate α=0.05.

Figure 99. Defiance 2008 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

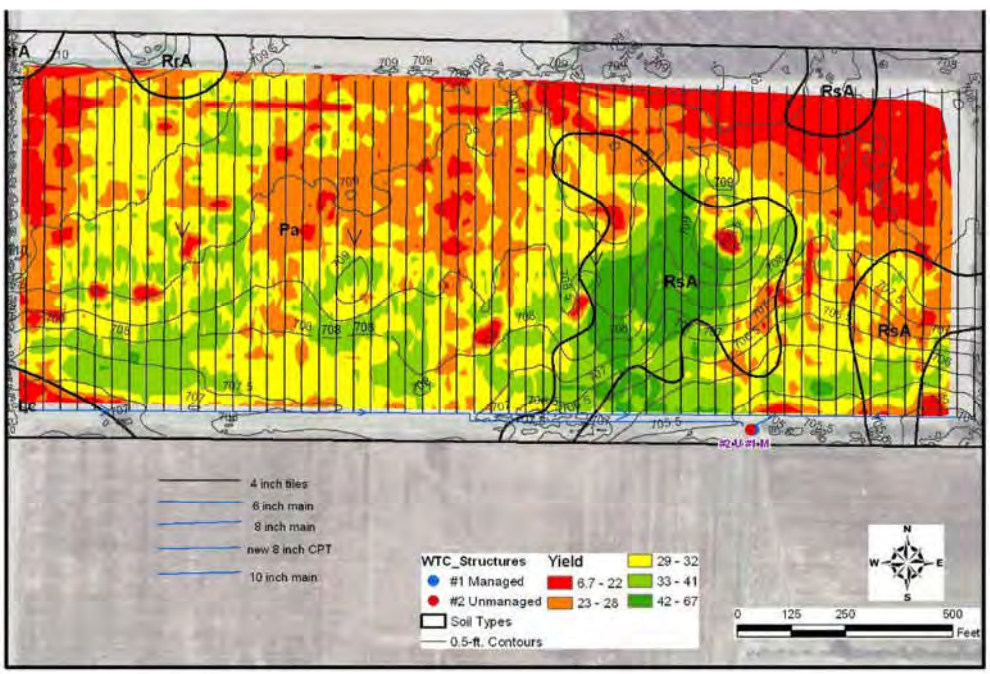


Figure 100. Napoleon 2008 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

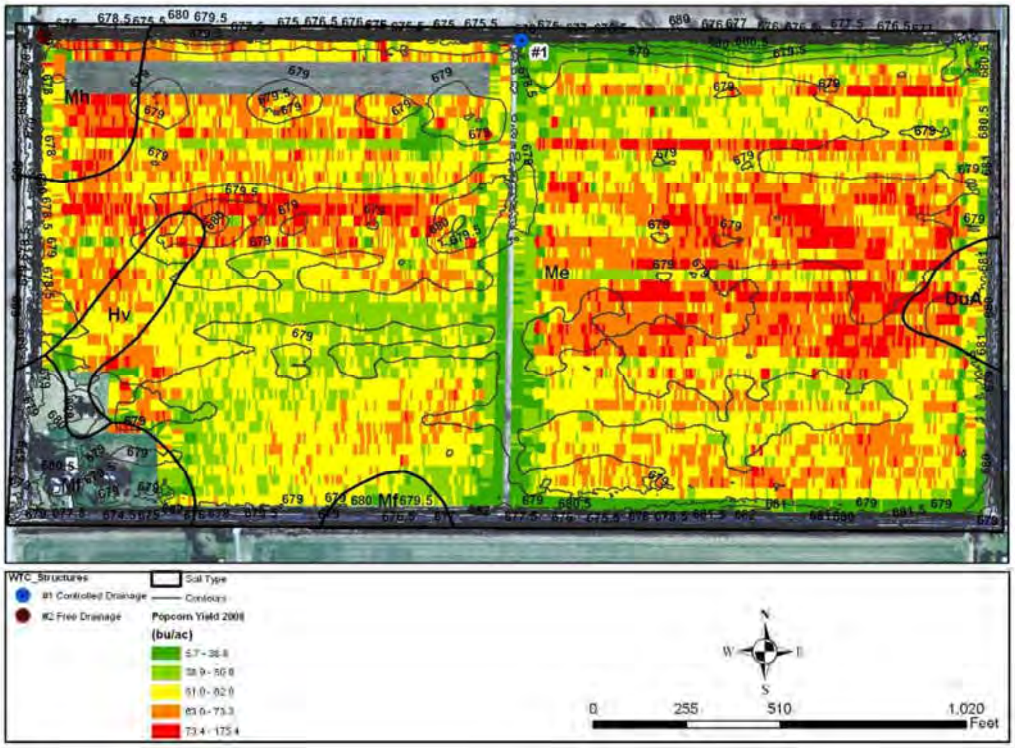


Figure 101. Dunkirk 2008 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

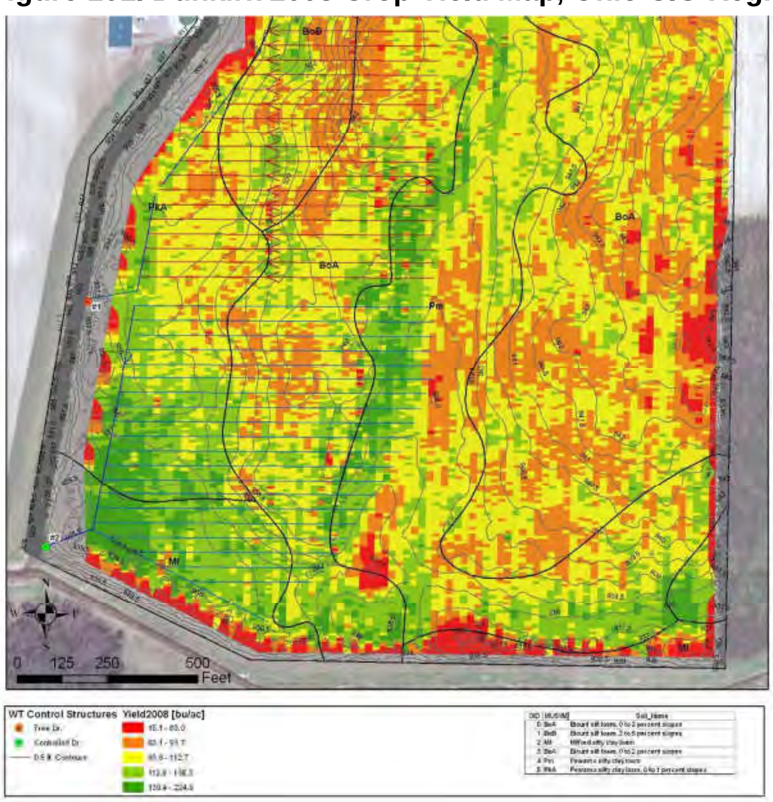


Figure 102 Lakeview 2008 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

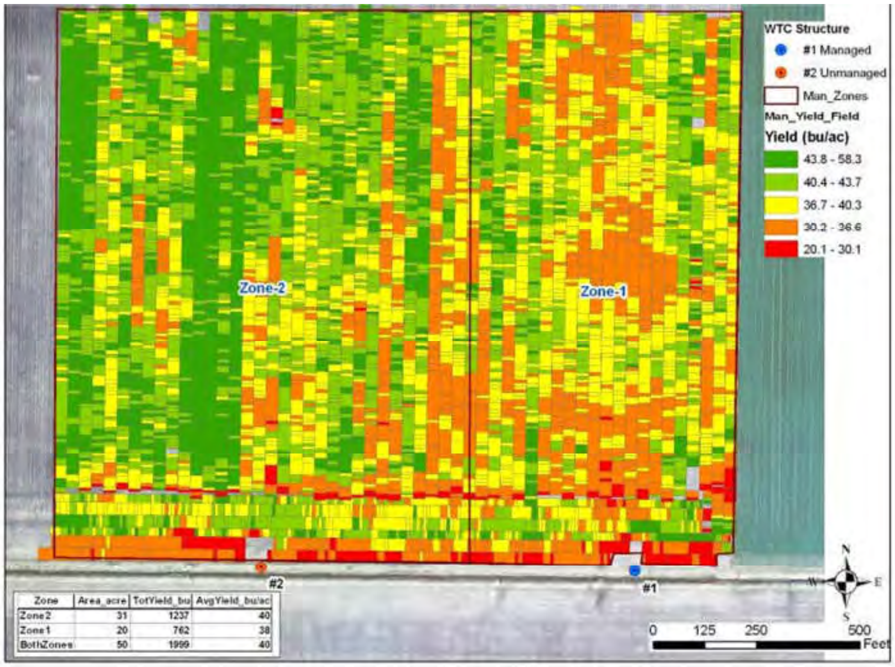


Table 26. Crop and yield summary of Ohio CIG regional sites in 2008, zone area-of-influence means.

Site Name	County	Crop	Management	Zone Area-of-Influence (acre)	Average Yield over Area-of-Influence (bu/ac)	Yield Increase (bu/ac)	Standard Error
Dunkirk	Hardin	Corn	Managed Drainage	5.5	122.1*	20.2	0.10
			Conventional Drainage	9.9	101.8*		0.13
Defiance	Defiance	Soybean	Managed Drainage	5.1	31.9*	2.9	0.41
			Conventional Drainage	1.2	29.0*		0.95

*- Means statistically significant using the two sample *t*-test at error rate α=0.05.

Table 27. Crop and yield summary of Ohio CIG regional sites in 2009, full zone means.

Site Name	County	Crop	Management	Zone Area (acre)	Average Yield over Full Zone (bu/ac)	Yield Increase (bu/ac)	Standard Error
Napoleon	Henry	Corn	Managed Drainage	38.3	214.1*	13.3	0.70
			Conventional Drainage	24.2	200.8*		0.69
Lakeview	Auglaize	Popcorn	Managed Drainage	19.8	49.5	0.1	11.16
			Conventional Drainage	30.6	49.4		12.76
Dunkirk	Hardin	Soybean	Managed Drainage	15.6	57.2*	2.2	0.23
			Conventional Drainage	13.0	54.9*		0.25
Defiance	Defiance	Corn	Managed Drainage	20.6	134.9*	4.0	0.39
			Conventional Drainage	19.4	130.9*		0.48

*- Means statistically significant using the two sample *t*-test at error rate α=0.05.

Figure 103. Defiance 2009 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

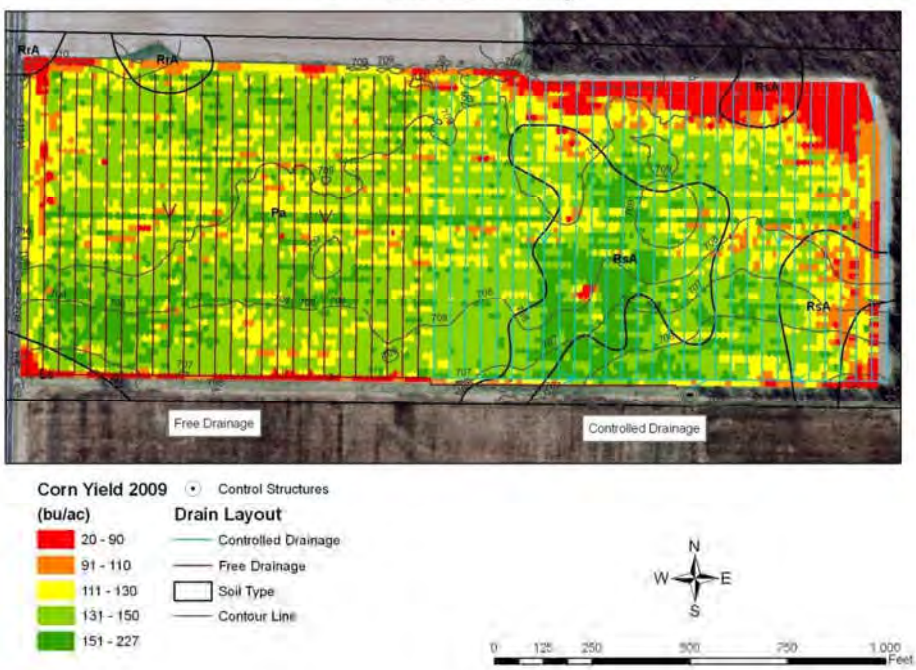


Figure 104. Napoleon 2009 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

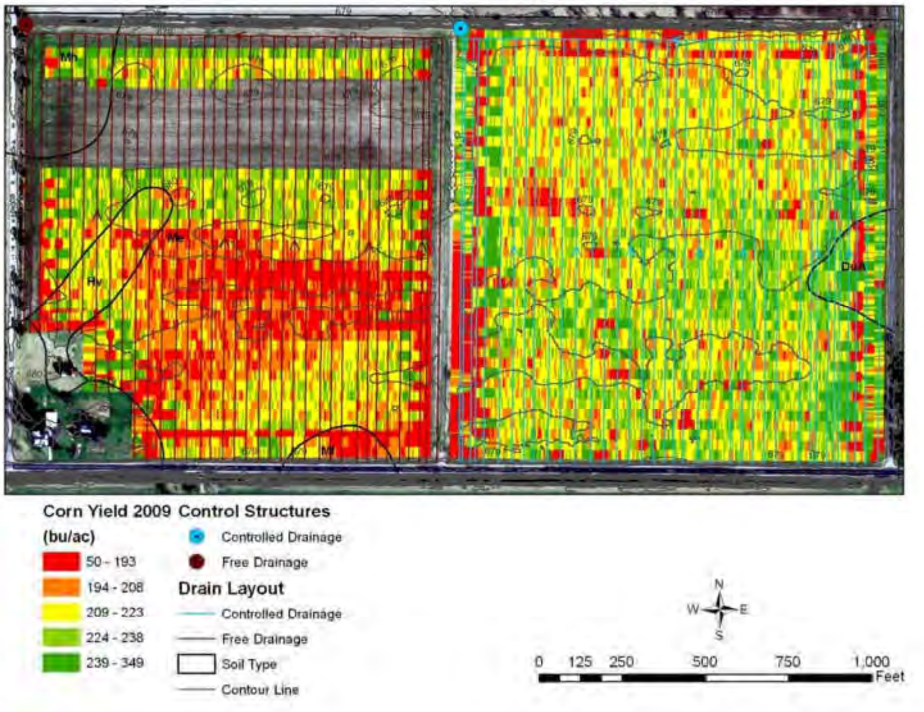


Figure 105. Dunkirk 2009 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

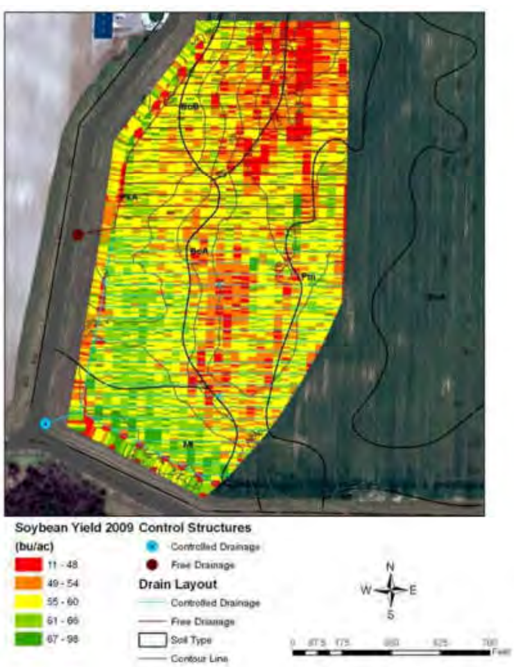


Figure 106. Lakeview 2009 Crop Yield Map, Ohio CIG Regional Site, Full Zones.

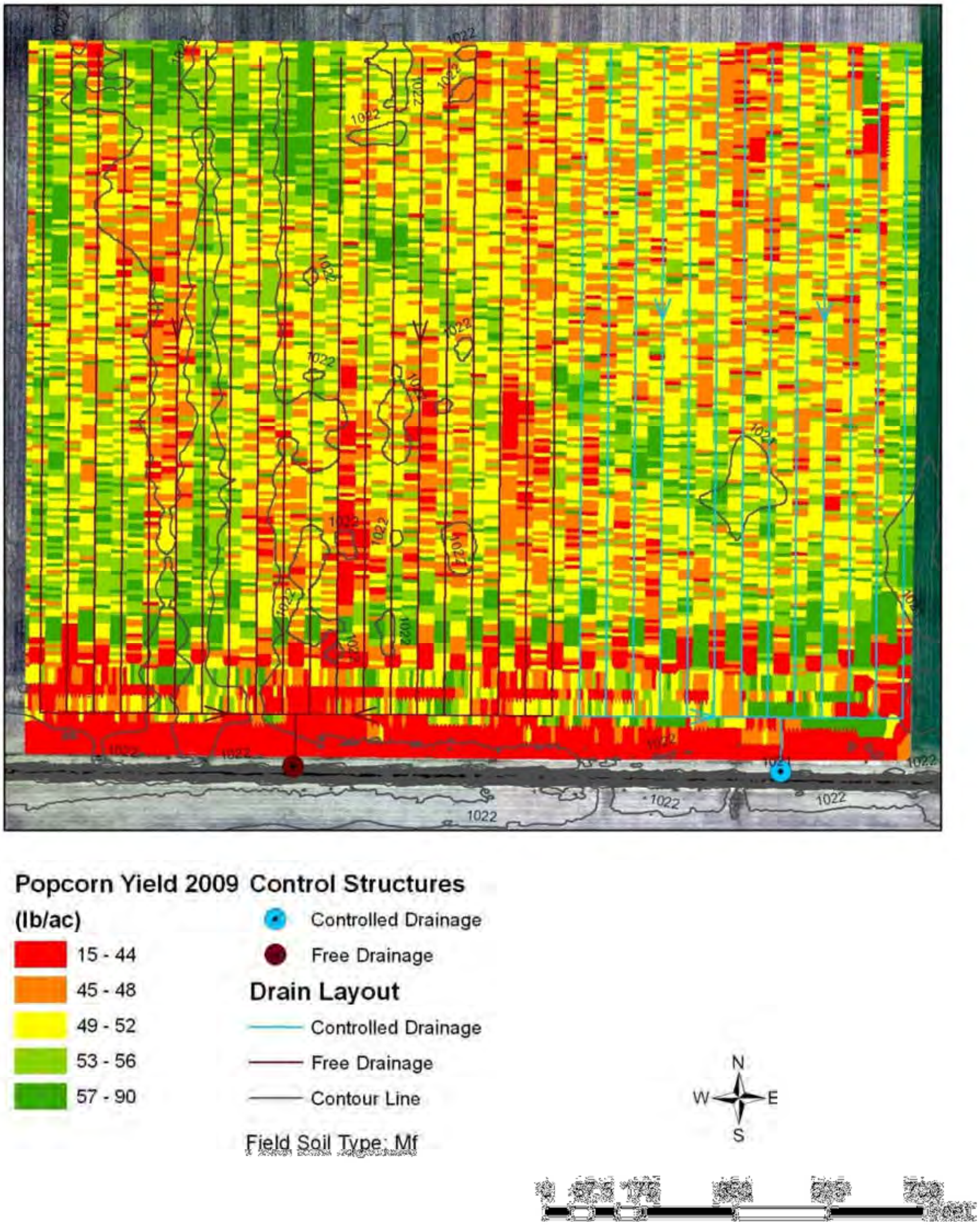


Table 28. Crop and yield summary of Ohio CIG regional sites in 2009, Zone Area-of-Influence means.

Site Name	County	Crop	Management	Zone Area-of-Influence (acre)	Average Yield over Area-of-Influence (bu/ac)	Yield Increase (bu/ac)	Standard Error
Dunkirk	Hardin	Soybean	Managed Drainage	5.5	58.6*	1.8	0.35
			Conventional Drainage	9.9	56.8*		0.43
Defiance	Defiance	Corn	Managed Drainage	5.1	138.2*	8.1	0.90
			Conventional Drainage	1.2	130.1*		2.31

***- Means statistically significant using the two sample *t*-test at error rate α=0.05.**

Figure 107. Defiance 2009 Crop Yield Map, Ohio CIG Regional Site, Zone Area-of-Influence.

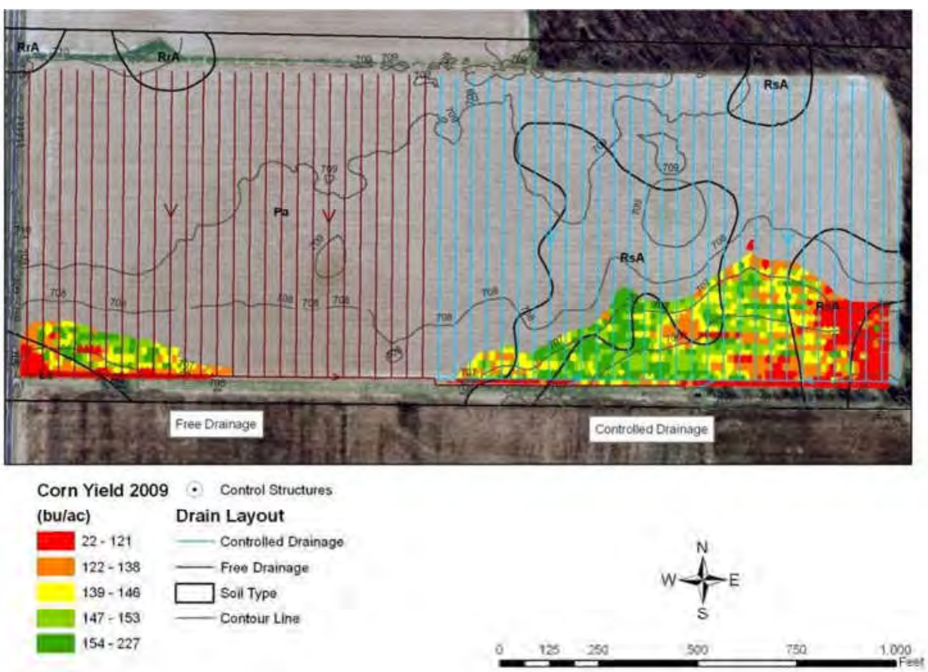


Figure 108. Napoleon 2009 Crop Yield Map, Ohio CIG Regional Site, 4688 VT3 Variety only.

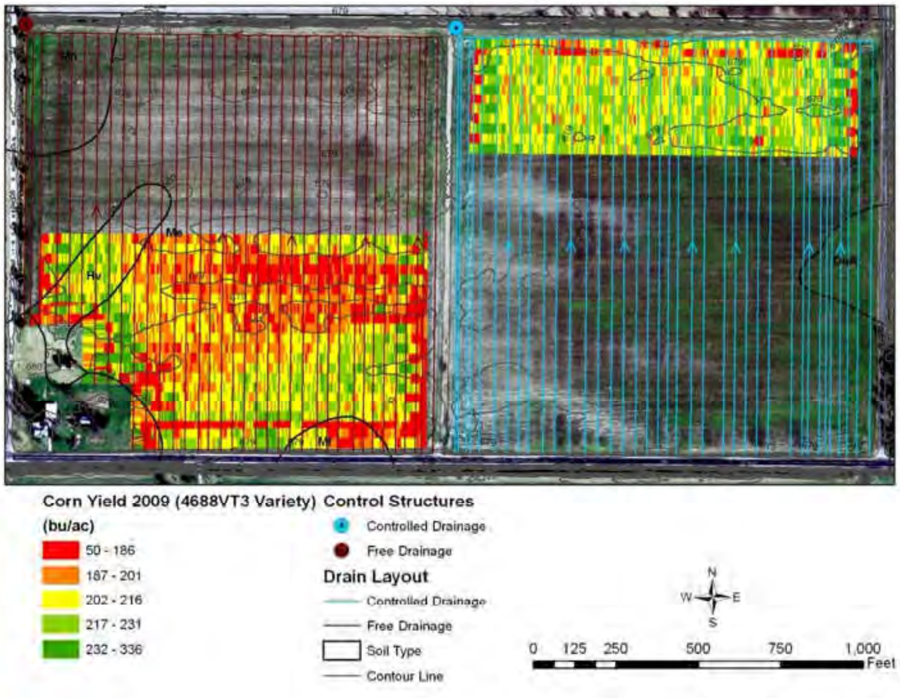
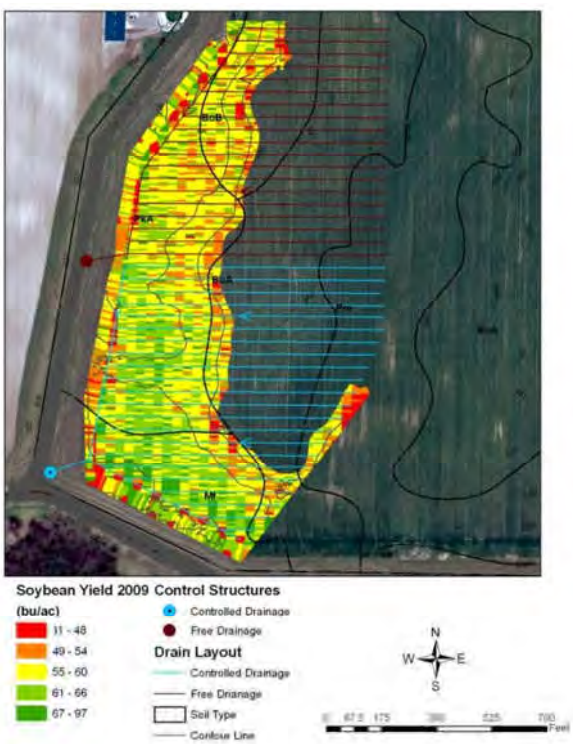


Figure 109. Dunkirk 2009 Crop Yield Map, Ohio CIG Regional Site, Zone Area-of-Influence.



Minnesota Precipitation

Table 29a. Dundas precipitation.

	Date	Precipitation	30yr Avg Precipitation	Deviation from Average
Annual Precipitation				
***partial year**	2007*	8.6	31.64	-23.04
	2008	21	31.64	-10.64
	2009	25.22	31.64	-6.42
Precipitation over cropping season April 1-October 31 (inch)				
***partial year**	2007*	4.74	31.64	-26.9
	2008	18.33	31.64	-13.31
	2009	21.84	31.64	-9.8

Table 29b. Hayfield precipitation.

	Date	Precipitation	30yr Avg Precipitation	Deviation from Average
Annual Precipitation				
***partial year**	2007*	11.59	30.14	-18.55
	2008	15.7	30.14	-14.44
	2009	24.55	30.14	-5.59
Precipitation over cropping season April 1-October 31 (inch)				
***partial year**	2007*	11.42	30.14	-18.72
	2008	12.86	30.14	-17.28
	2009	21.37	30.14	-8.77

Table 29c. Wilmont precipitation.

	Date	Precipitation	30yr Avg Precipitation	Deviation from Average
Annual Precipitation				
***partial year**	2007*	7.56	27.79	-20.23
	2008	29.1	27.79	1.31
	2009	22.94	27.79	-4.85
Precipitation over cropping season April 1-October 31 (inch)				
***partial year**	2007*	7.52	27.79	-20.27
	2008	23.41	27.79	-4.38
	2009	20.43	27.79	-7.36

Table 29d. Windom precipitation.

	Date	Precipitation	30yr Avg Precipitation	Deviation from Average
Annual Precipitation				
***partial year**	2007*	NA	29	
	2008	27	29	-2
	2009	27.37	29	-1.63
Precipitation over cropping season April 1-October 31 (inch)				
***partial year**	2007*	NA	29	
	2008	25.88	29	-3.12
	2009	22.45	29	-6.55

Minnesota Drainage Outflows

Table 30a. Dundas annual drainage outflows.

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	NA	NA	NA	NA	NA	NA
2008	2.37	2.56	7%	4.11	6.54	37%
2009	0.29	0.35	17%	1.55	4.47	65%

Table 30b. Dundas cropping season drainage outflows.

Year	Cropping Season Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	NA	NA	NA	NA	NA	NA
2008	2.37	2.56	7%	4.11	6.54	37%
2009	0.29	0.27	-7%	1.55	4.47	65%

Table 30c. Hayfield annual drainage outflows **.

Year	Annual Flow (in)				Annual Nitrate Loss (lbs/acre)			
	Managed	Conv	Conv	% Diff	Managed	Conv	Conv	% Diff
2007	NA	NA	NA	NA	NA	NA	NA	NA
2008	8.1	7.4	4.4	-9%	39.4	39.2	22.9	-1%
2009	3.3	3.8	2.4	13%	9.7	8.7	4.2	-11%

Table 30d. Hayfield cropping season drainage outflows **.

Year	Cropping Season Flow (in)				Annual Nitrate Loss (lbs/acre)			
	Managed	Conv	Conv	% Diff	Managed	Conv	Conv	% Diff
2007	NA	NA	NA	NA	NA	NA	NA	NA
2008	8	7.3	4.3	-10%	39.4	39.2	22.9	-1%
2009	3.1	3.5	2.2	11%	9.7	8.7	4.2	-11%

Table 30e. Wilmont annual drainage outflows.

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	NA	NA	NA	NA	NA	NA
2008	4.5	4.2	-7%	12.3	13	5%
2009	0.6	2.4	75%	0.2	8.4	98%

Table 30f. Wilmont cropping season drainage outflows.

Year	Cropping Season Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007	NA	NA	NA	NA	NA	NA
2008	4.5	4.1	-10%	12.3	13	5%
2009	0.4	2	80%	0.2	8.4	98%

Table 30g. Windom annual drainage outflows.

Year	Annual Flow (in)				Annual Nitrate Loss (lbs/acre)			
	Conv	Managed	Managed – W	% Diff	Conv	Managed	Managed – W	% Diff
2007	NA	NA	NA	NA	NA	NA	NA	NA
2008 *	NA	12.8	9.4	NA	NA	34.2	23.8	NA
2009	6.3	1.8	1.4	78%	6.3	2.7	2.5	60%

Table 30h. Windom cropping season drainage outflows.

Year	Cropping Season Flow (in)				Annual Nitrate Loss (lbs/acre)			
	Managed	Conv	Conv	% Diff	Managed	Conv	Conv	% Diff
2007	NA	NA	NA	NA	NA	NA	NA	NA
2008 *	NA	12.8	9.4	NA	NA	34.2	23.8	NA
2009	6.1	1.8	1.3	79%	6.3	2.7	2.5	60%

*2008 Flow only represent Mid & West sites conventional drainage only, Mid is the Conventional site for comparison. The sites were not set up until drainage had already occurred for the season. 2009 drainage: West is Managed, Mid is Conventional, East is Managed with other experiments occurring at site. Due to separate experiments the East site is reported but not used in comparison to the other sites.

**Hayfield Site 1 & 2 are 35 ft spacing, Site 3 is 70 ft spacing; due to this site 3 is reference only and not compared to other sites. Site 1 is managed and compared to Site 2 which is conventional.

2007 monitoring equipment set up after most drainage had already occurred for the season; therefore nothing to report.

Minnesota Crop Yields

Table 31a. Dundas yield results.

			CORN	SOYBEANS
Site ID	2006 (bu)	2007 (bu)	2008 (bu)	2009 (bu)
North-Conventional	-------	-------	180	54
South-Managed	-------	-------	185	54
Field Average	-------	-------	176	52

Table 31b. Hayfield yield results.

		CORN	SOYBEANS	CORN
Site ID	2006 (bu)	2007 (bu)	2008 (bu)	2009 (bu)
Site 1-Managed	-------	204	51	207
Site 2-Conventional	-------	204	57	197
Site –Conventional	-------	205	53	204
Field Average	-------	205	55	200

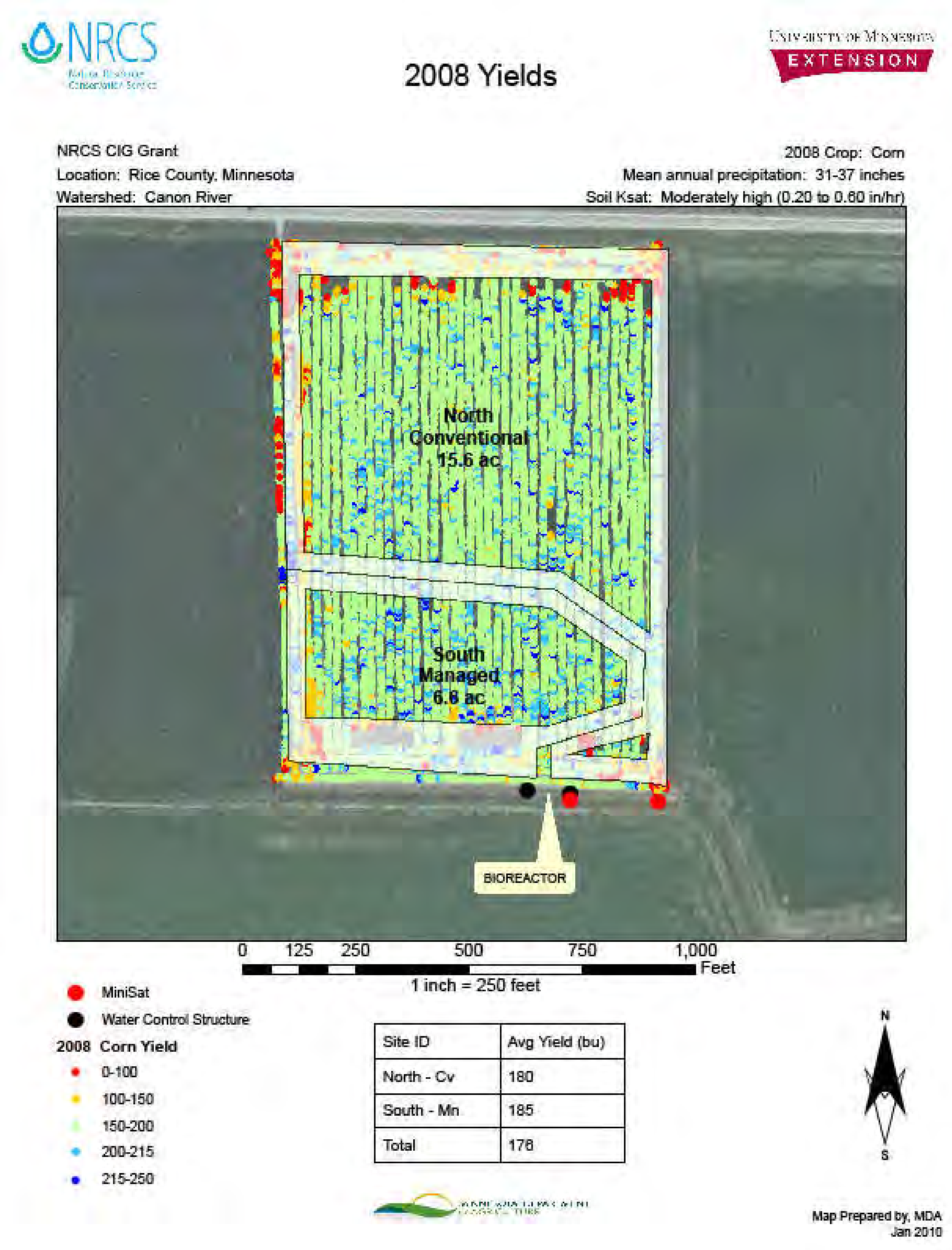
Table 31c. Wilmont yield results.

			CORN	CORN
Site ID	2006 (bu)	2007 (bu)	2008 (bu)	2009 (bu)
North-Managed	-------	-------	168	173
South-Conventional	-------	-------	173	175
Field Average	-------	-------	160	174

Table 31d. Windom yield results.

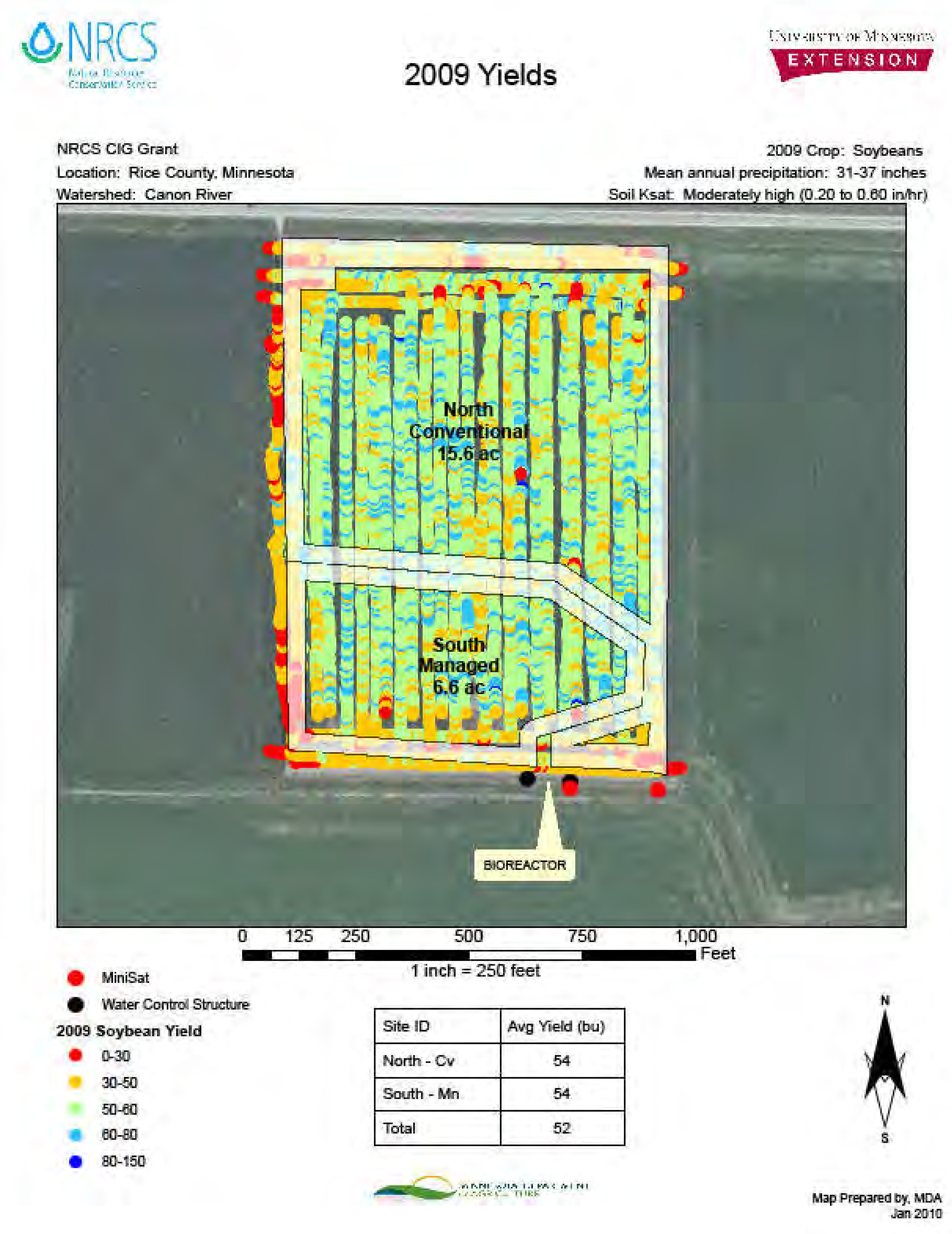
			SOYBEANS	CORN
Site ID	2006 (bu)	2007 (bu)	2008 (bu)	2009 (bu)
West-Managed	-------	-------	49	187
Mid-Conventional	-------	-------	48	187
East-Conventional	-------	-------	46	185
Field Average	-------	-------	47	185

Figure 110. Dundas yield map.



Site ID	Avg Yield (bu)
North - Cv	180
South - Mn	185
Total	178

Figure 111. Dundas yield map.



Site ID	Avg Yield (bu)
North - Cv	54
South - Mn	54
Total	52

Figure 112. Hayfield yield map.

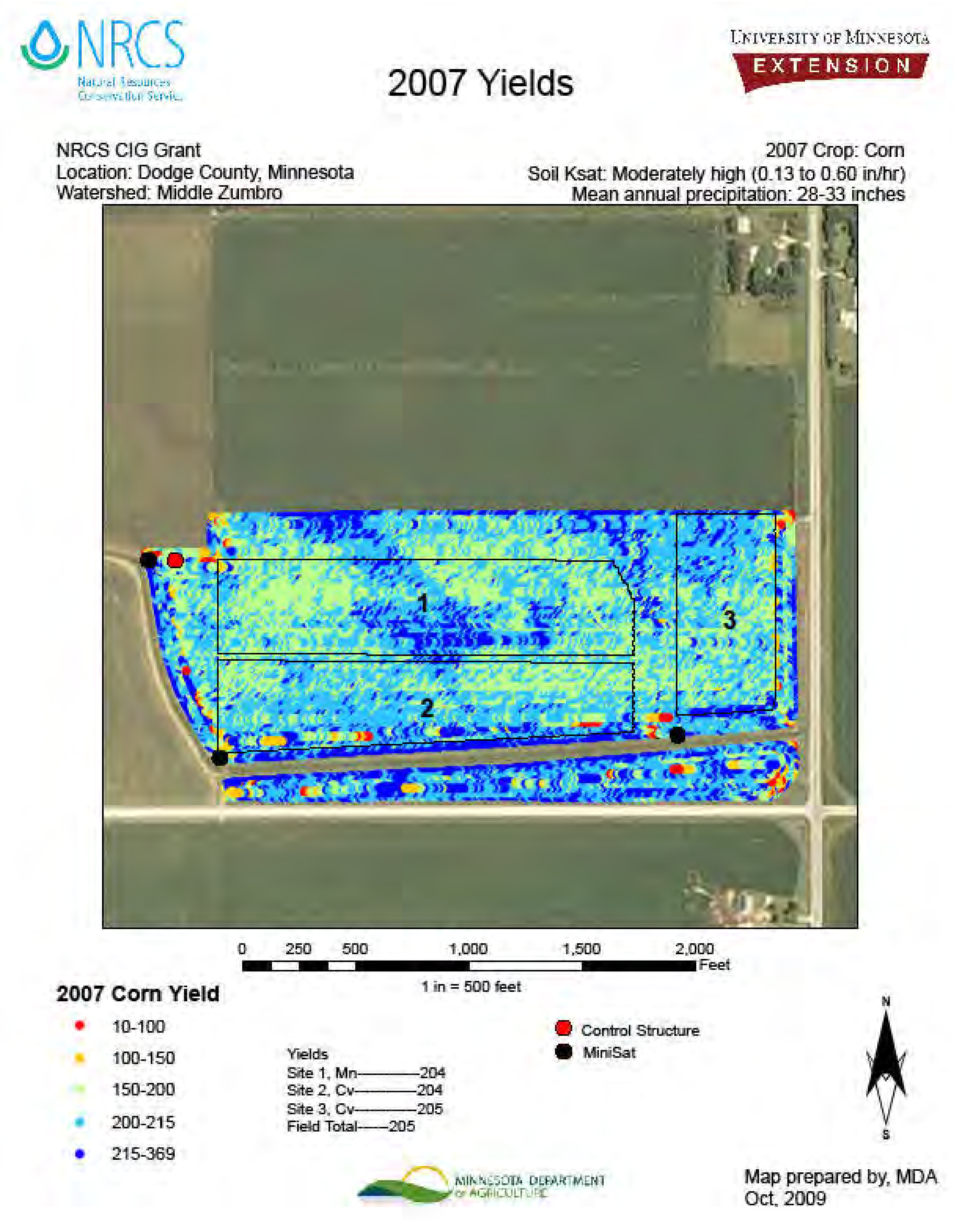


Figure 113. Hayfield yield map.

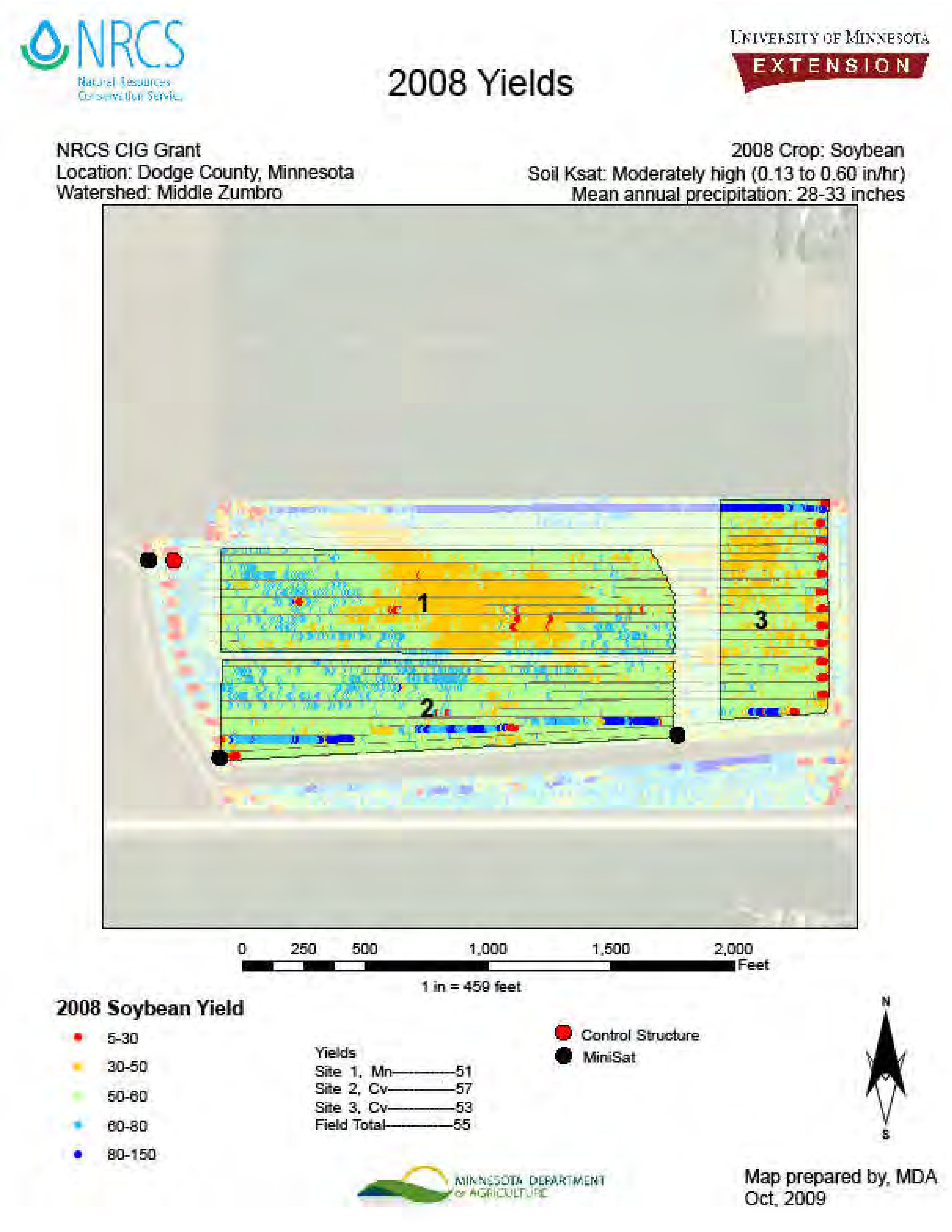


Figure 114. Hayfield yield map.

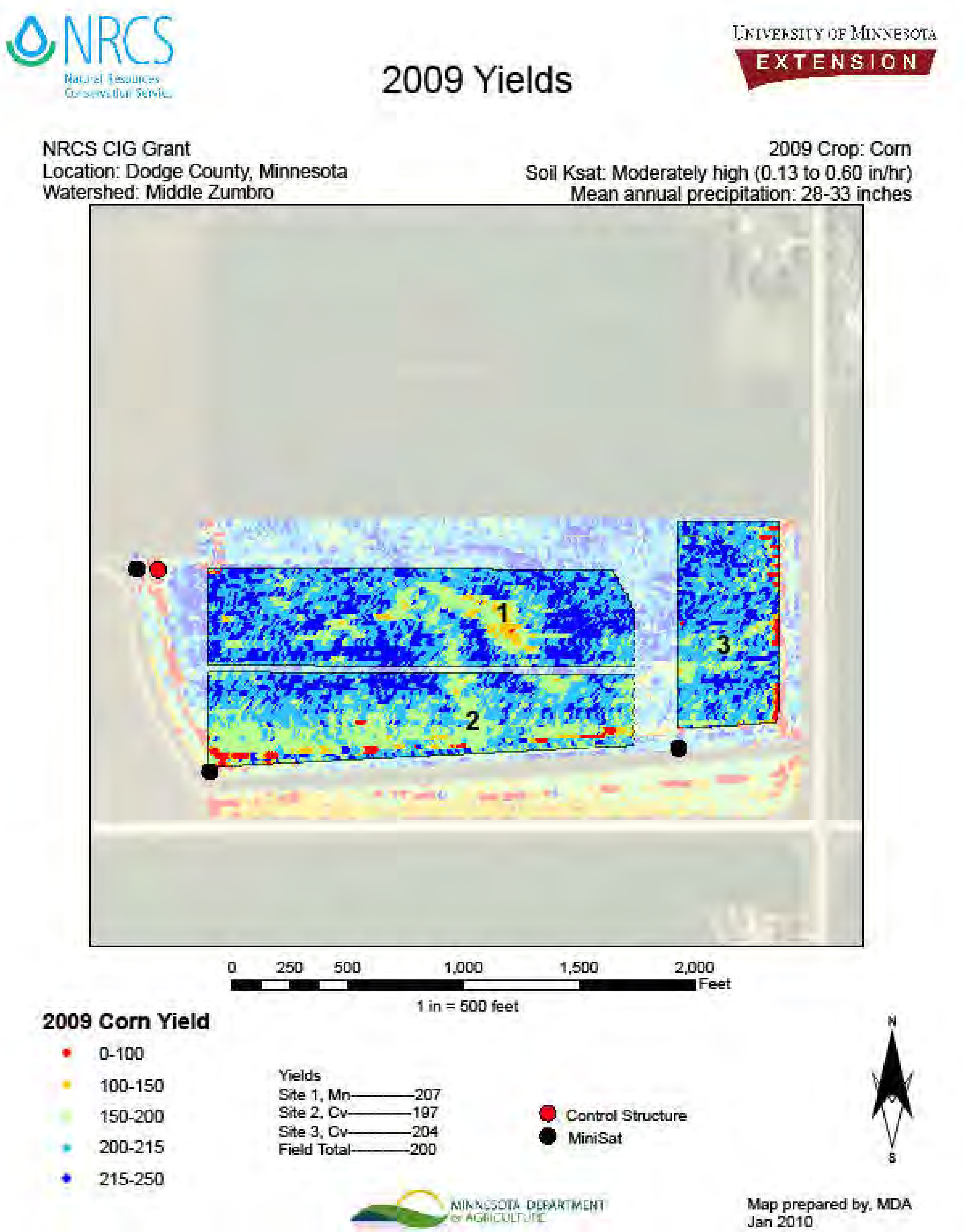
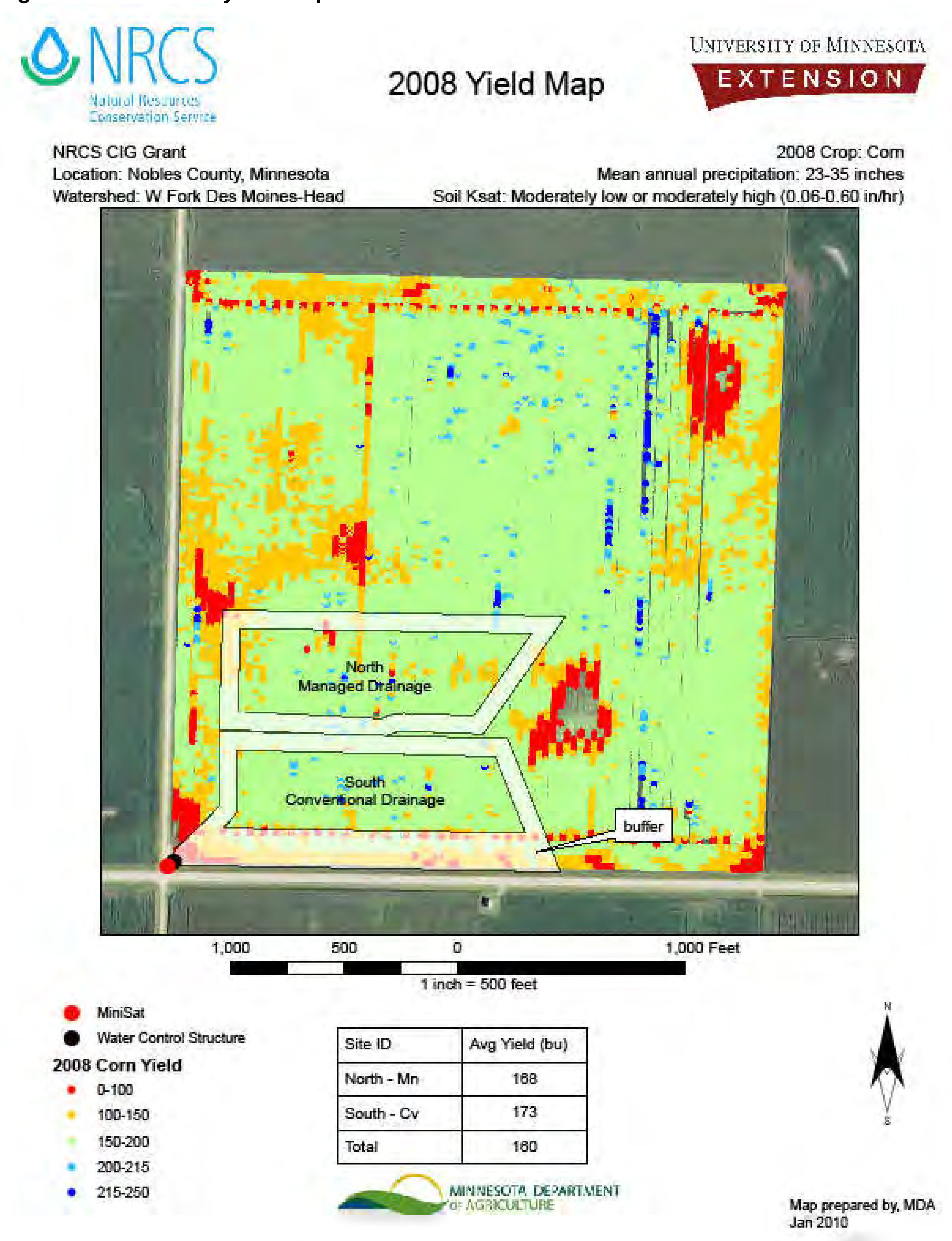


Figure 115. Wilmont yield map.



Site ID	Avg Yield (bu)
North - Mn	168
South - Cv	173
Total	160

Figure 116. Wilmont yield map.

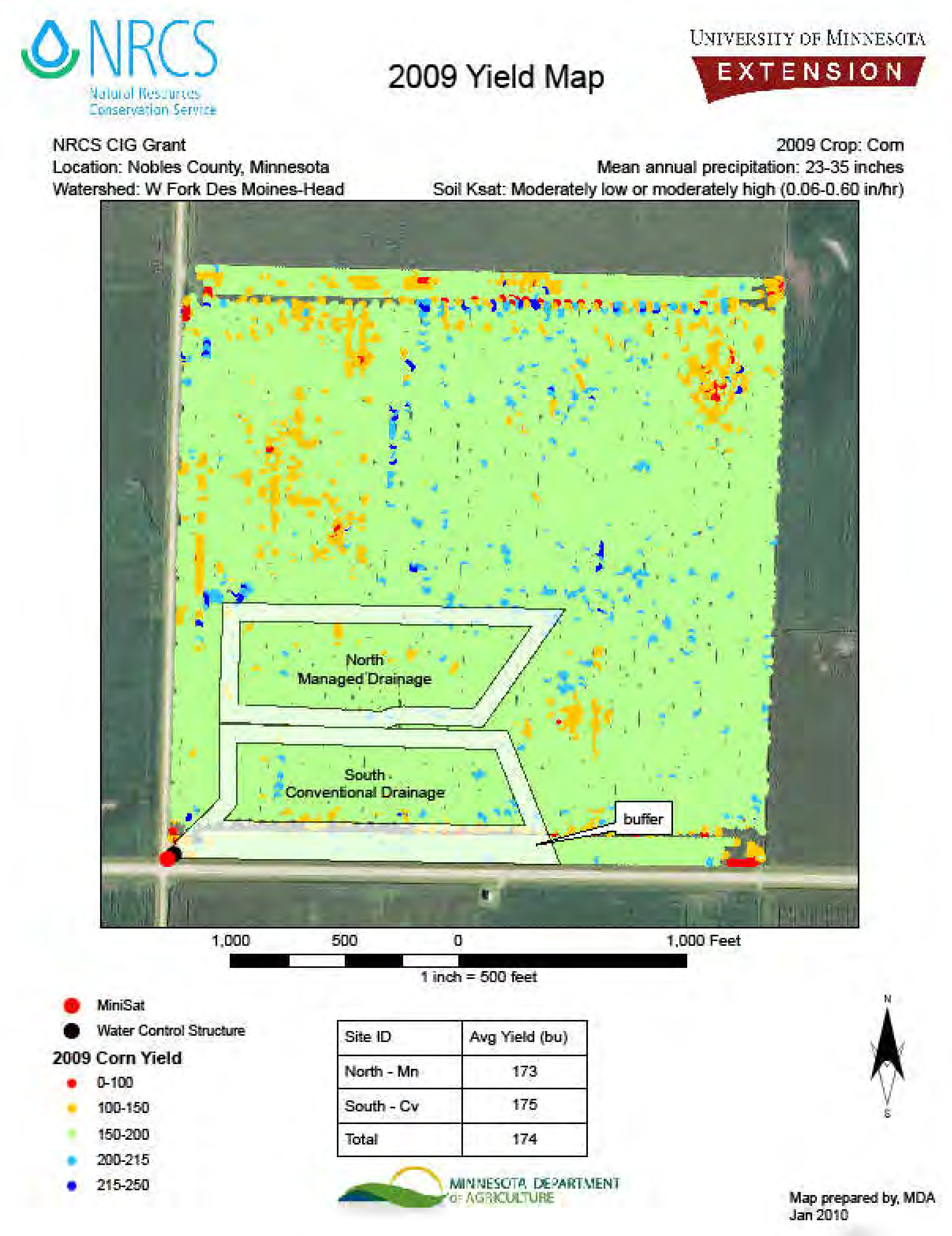
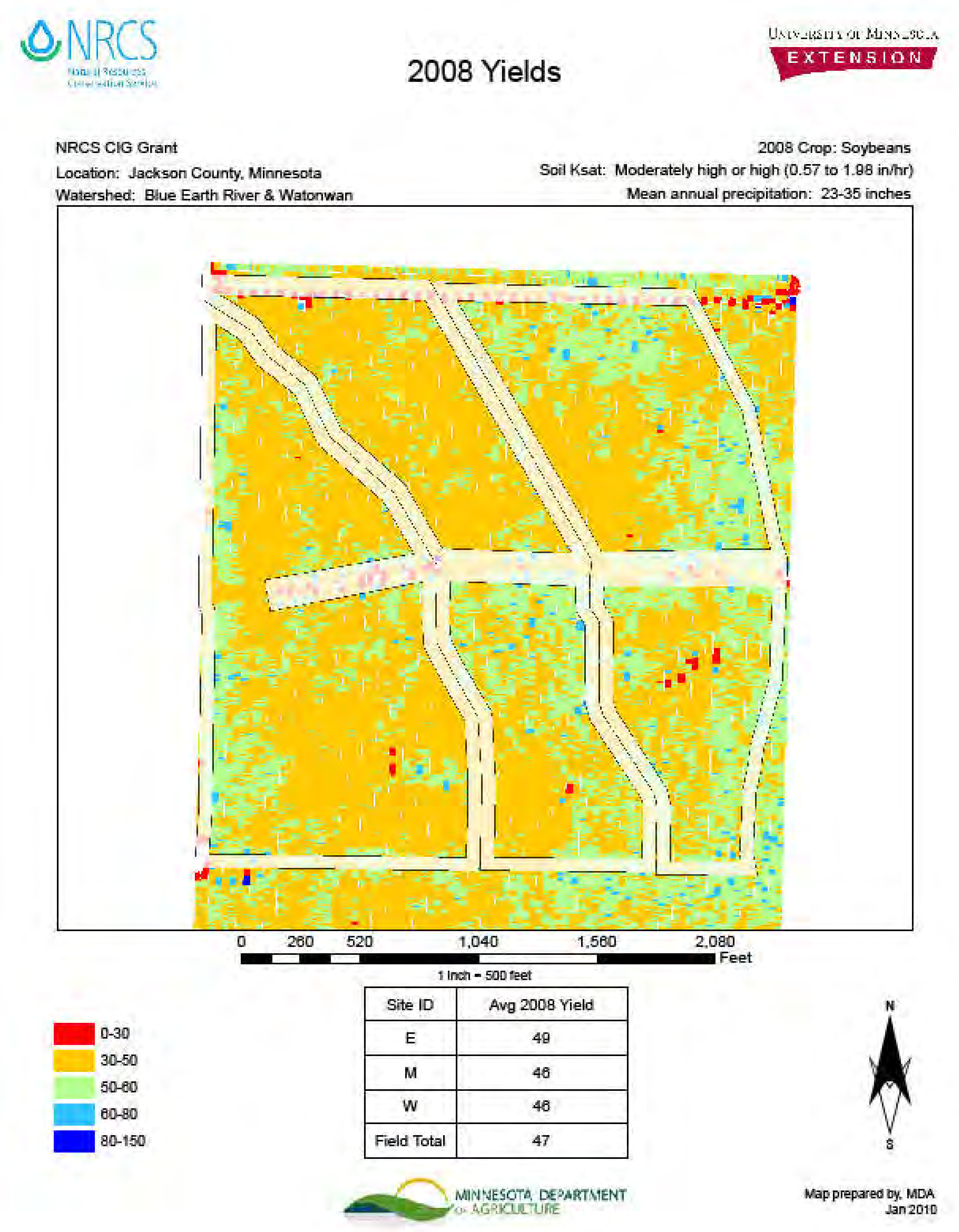
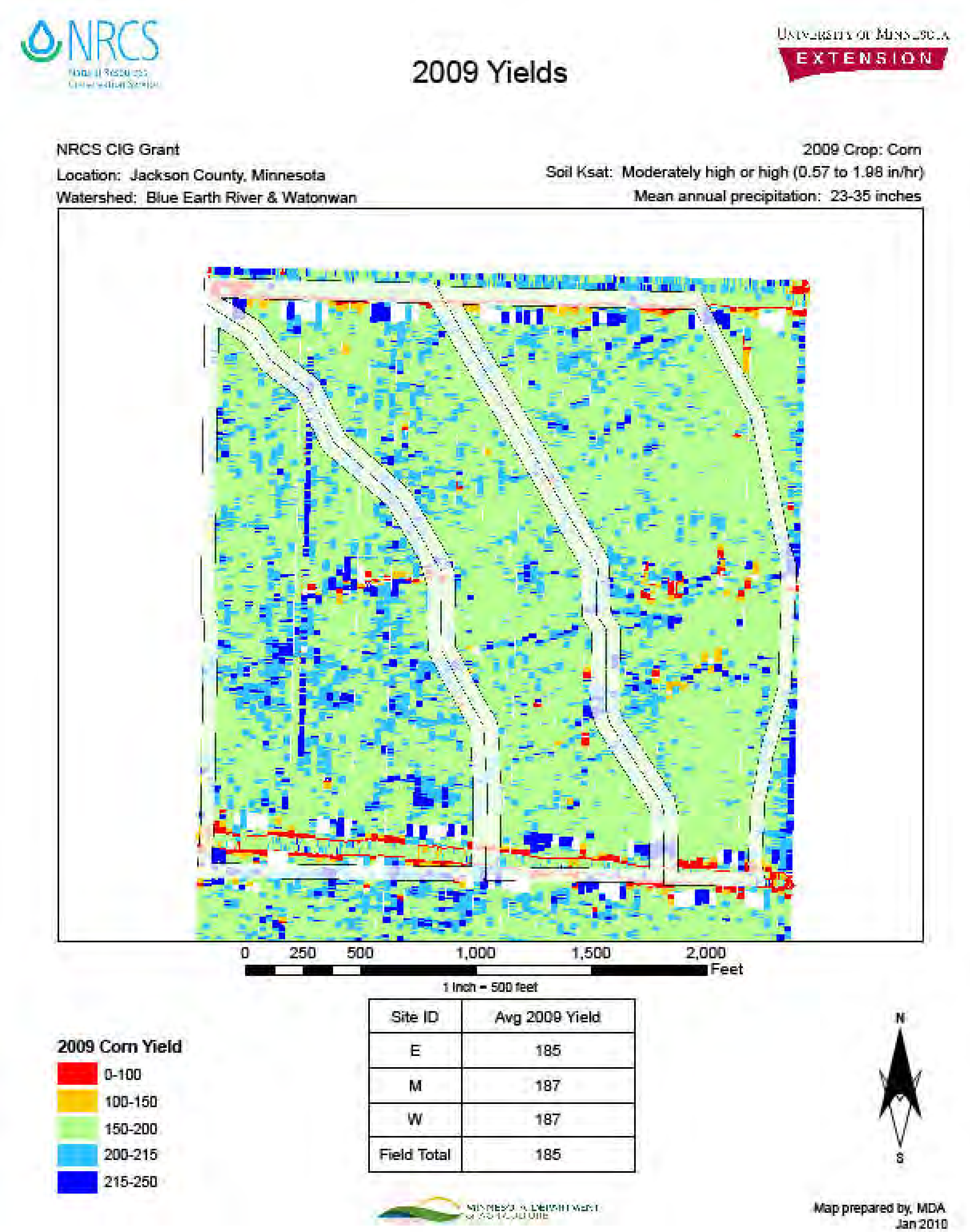


Figure 117. Windom yield map.



Site ID	Avg 2008 Yield
E	49
M	46
W	46
Field Total	47

Figure 118. Windom yield map.



Site ID	Avg 2009 Yield
E	185
M	187
W	187
Field Total	185

Illinois Precipitation

Figure 119a. Precipitation data for sites 1 and 2 (Hume, Illinois).

Time Period	Annual Precipitation (in)		Growing Season Precipitation (in)	
	Value	Deviation from Mean	Value	Deviation from Mean
30 Year Mean	38.76	0	16.19	0
2006	41.86	3.1	19.69	3.5
2007	33.27	-5.49	8.85	-7.34
2008	53.36	14.6	27.68	11.49
2009	53.12	14.36	25.29	9.1

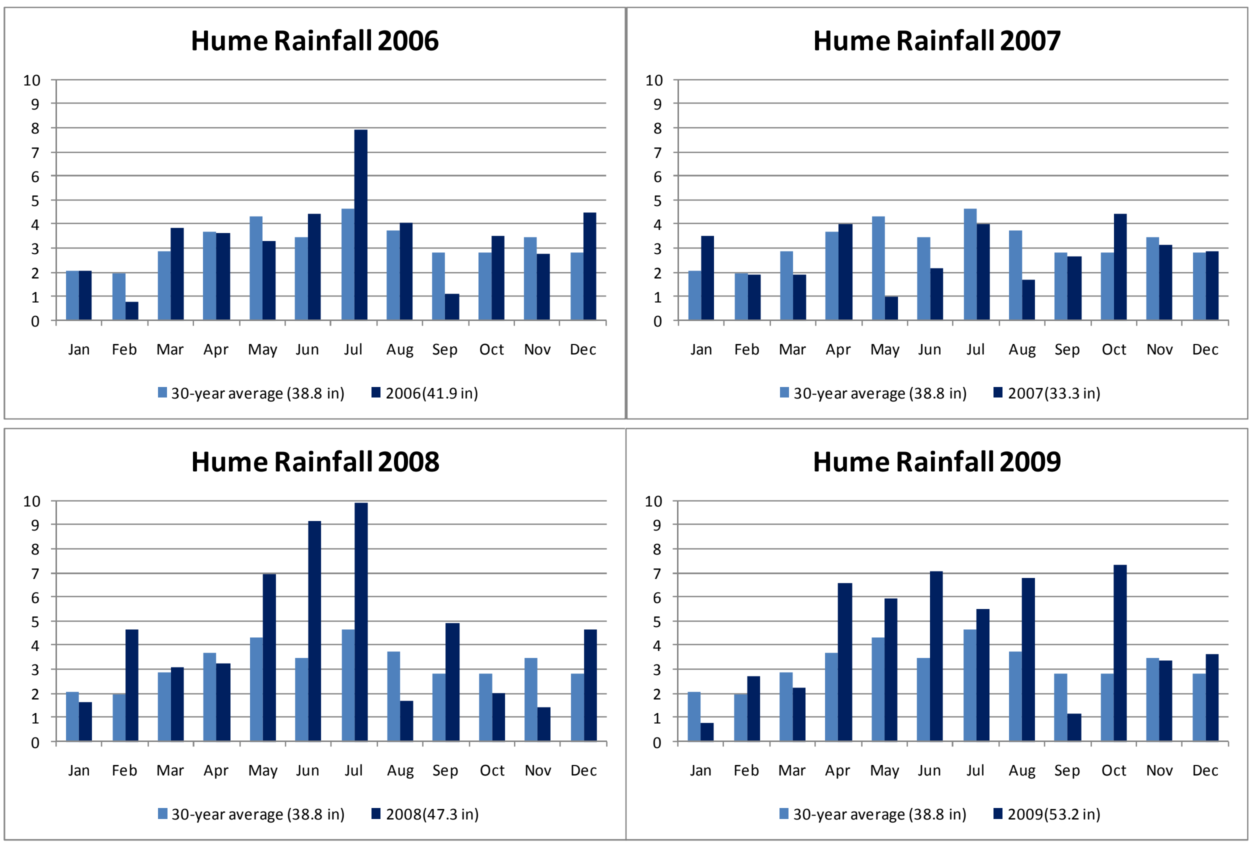
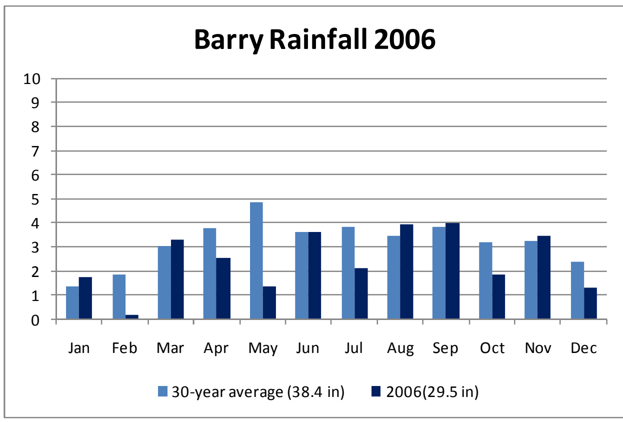
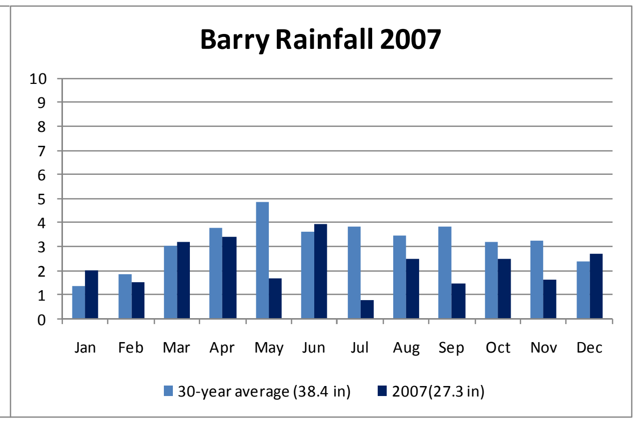
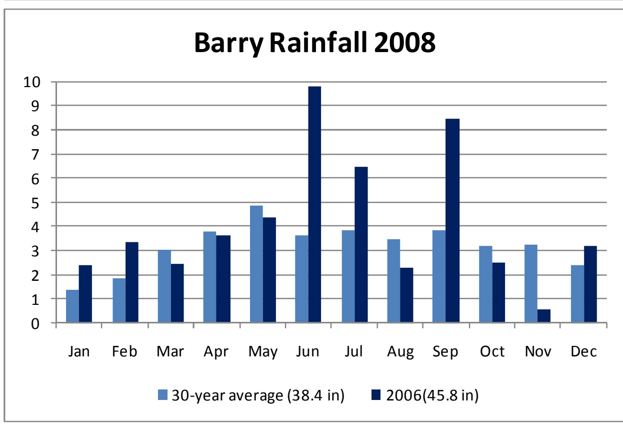


Figure 119b. Precipitation data for site 3 (Barry, Illinois).

Time Period	Annual Precipitation (in)		Growing Season Precipitation (in)	
	Value	Deviation from Mean	Value	Deviation from Mean
30 Year Mean	38.44	0	15.75	0
2006	29.47	-8.97	11.03	-4.72
2007	27.31	-11.13	8.85	-6.9
2008	49.5	11.06	22.94	7.19
2009	46.91	8.47	20.44	4.69







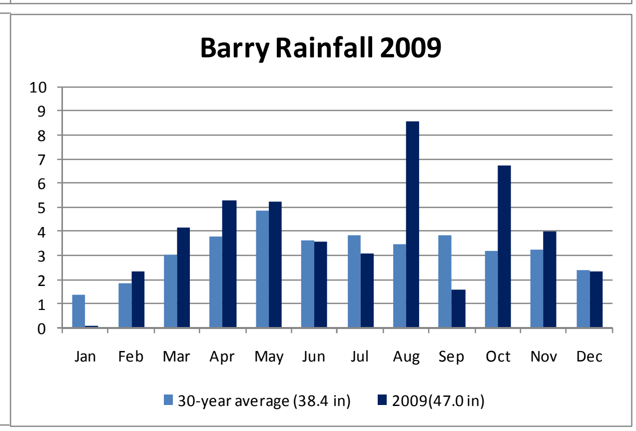
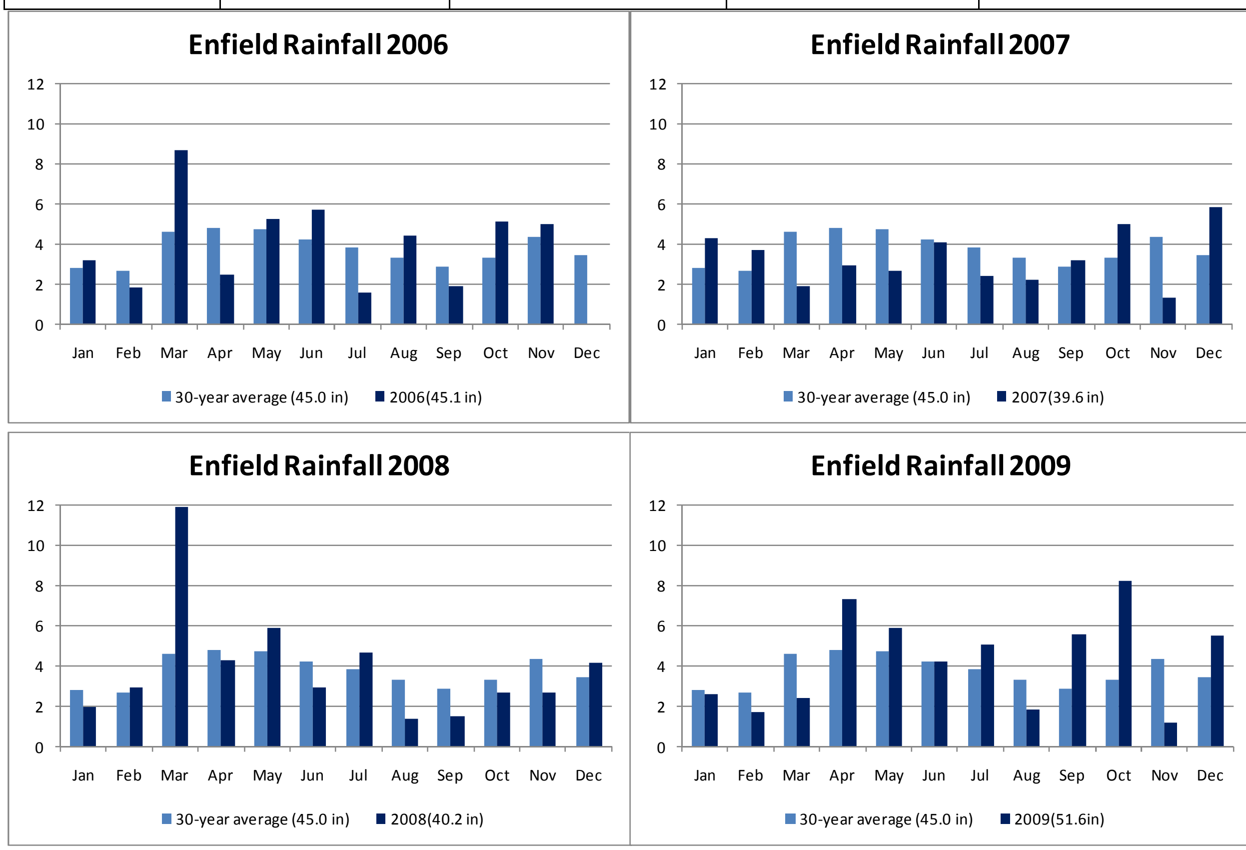


Figure 119c. Precipitation data for site 4 (Enfield, Illinois).

Time Period	Annual Precipitation (in)		Growing Season Precipitation (in)	
	Value	Deviation from Mean	Value	Deviation from Mean
30 Year Mean	45	0	16.11	0
2006	45.12	0.12	16.94	0.83
2007	39.6	-5.4	11.37	-4.74
2008	47.05	2.05	14.88	-1.23
2009	51.56	6.56	17.03	0.92



<u>Illinois Drainage Outflows</u>

There was a high level of uncertainty associated with the measurement of flow, and consequently with the estimation of annual subsurface drainage volume and loads. This uncertainty was mainly due to two factors:

- The Magmeter flow meters give zero readings for flows less than 20 gpm (0.12 inches/day) at Barry, and 30 gpm (0.04 inches/day) at Hume.
- The weirs in the structures do not give accurate results under submerged outlet conditions. There were many occasions when the tile outlets were submerged.

In an attempt to reduce this uncertainty, a triangular weir/orifice equation was developed and tested at the sites. One tile outlet was instrumented with four different flow measurement devices to obtain a comparison between them. A procedure was developed to back-calculate flow under submerged outlet conditions where possible.

Table 32a: Hume North annual drainage outflows.

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	11.26	22.88	50.77%	33.03	95.67	65.47%
2009	11.58	31.35	63.05%	19.00	100.63	81.12%

Table 32b: Hume North growing season drainage outflows.

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	5.83	9.07	35.77%	17.38	5.18	-235.43%
2009	2.62	13.83	81.03%	5.65	51.09	88.93%

Note: The growing season was designated as May 1 through August 31.

Table 33a: Hume South annual drainage outflows.

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	14.83	29.74	50.15%			
2009	8.39	24.16	65.27%	17.71	82.34	78.49%

Table 33b: Hume South growing season drainage outflows.

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	9.21	10.56	12.76%			
2009	2.05	14.27	85.66%	5.40	53.42	89.89%

Note: The growing season was designated as May 1 through August 31.

Table 34a: Barry annual drainage outflows.

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	0.81	21.22	96.20%			
2009	1.58	8.58	81.55%	3.58	17.44	79.48%

Table 34b: Barry growing season drainage outflows.

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	0.33	4.72	93.07%			
2009	0.16	1.43	88.88%	0.38	3.77	89.93%

Note: The growing season was designated as May 1 through August 31.

Table 35a: Enfield annual drainage outflows.

Year	Annual Flow (in)			Annual Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	24.90	32.60	23.62%			
2009	8.46	13.13	35.56%	14.07	21.73	35.27%

Table 35b: Enfield growing season drainage outflows.

Year	Growing Season Flow (in)			Growing Season Nitrate Loss (lbs/acre)		
	Managed	Conventional	% Difference	Managed	Conventional	% Difference
2007						
2008	1.03	12.32	91.63%			
2009	1.69	6.90	75.56%	2.81	11.54	75.68%

Note: The growing season was designated as May 1 through August 31.

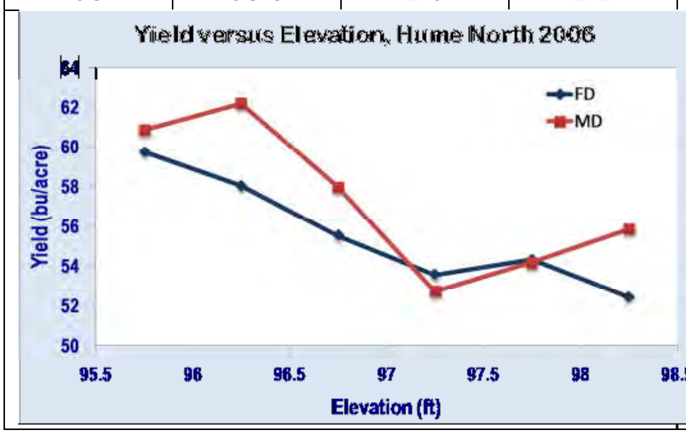
Illinois Crop Yields

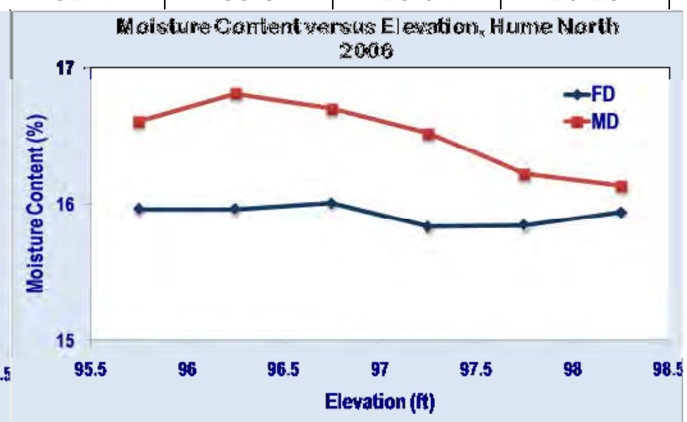
We developed a routine for the analysis of yield shape files, and for comparing yields from two fields. This routine can be used to:

- Determine if a normal distribution can be fitted to the yield data and, when necessary, evaluate yield moments using a reweighted least median of squares procedure;
- Plot yield histograms and determine if the yield histograms from two fields are from the same distribution;
- Determine the yield value with any exceedance probability using both parametric and non parametric procedures;
- Evaluate the relationships between yield and other variables in the yield file, such as elevation, using a novel robust regression procedure;
- Overlay yield and elevation maps and extract yield at any elevation increment;
- Create a contour shape file or grid file from any variable in the yield file, and
- Produce a plot of a yield map using specified intervals or a gradient color scheme.

Figure 120a. Hume North, 2006, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	**Upper**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**
95.73	**98.26**	**100**		**57.2**		**15.98**	
95.69	**98.21**		**100**		**58.6**		**16.66**
95.69	**97**		**77***		**60.2**		**16.72**
95.5	96	16.3	14.9	59.7	60.9	15.96	16.60
96	96.5	45.0	30.2	58.0	62.2	15.96	16.81
96.5	97	29.0	31.7	55.5	58.0	16.01	16.70
97	97.5	6.3	15.8	53.6	52.7	15.83	16.52
97.5	98	2.5	5.4	54.3	54.2	15.84	16.22
98	98.5	1.0	2.1	52.4	55.8	15.94	16.13

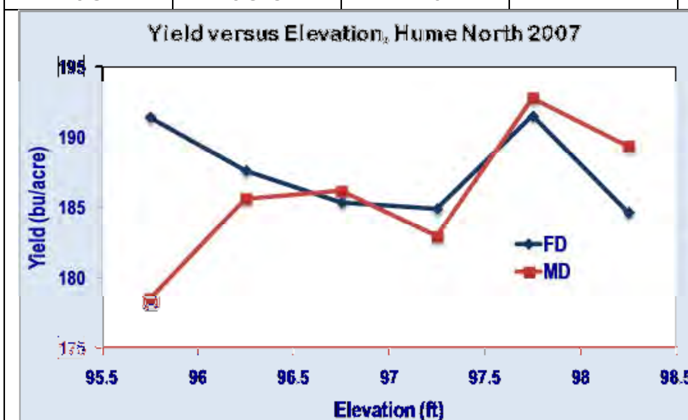


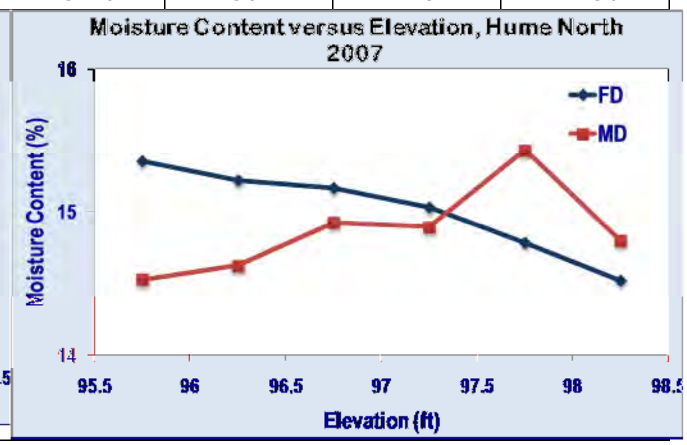


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 120b. Hume North, 2007, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
95.73	**98.26**	**100**		**187.6**		**15.21**	
95.69	**98.21**		**100**		**184.9**		**14.81**
95.69	**98.21**		**77***		**184.5**		**14.74**
95.5	96	16.3	14.9	191.4	178.5	15.36	14.53
96	96.5	45.0	30.2	187.6	185.6	15.22	14.63
96.5	97	29.0	31.7	185.4	186.2	15.17	14.92
97	97.5	6.3	15.8	184.9	182.9	15.03	14.90
97.5	98	2.5	5.4	191.5	192.8	14.78	15.43
98	98.5	1.0	2.1	184.6	189.4	14.52	14.80

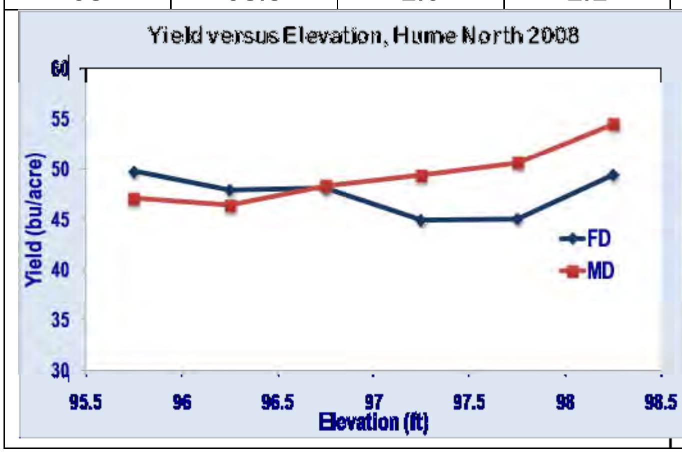


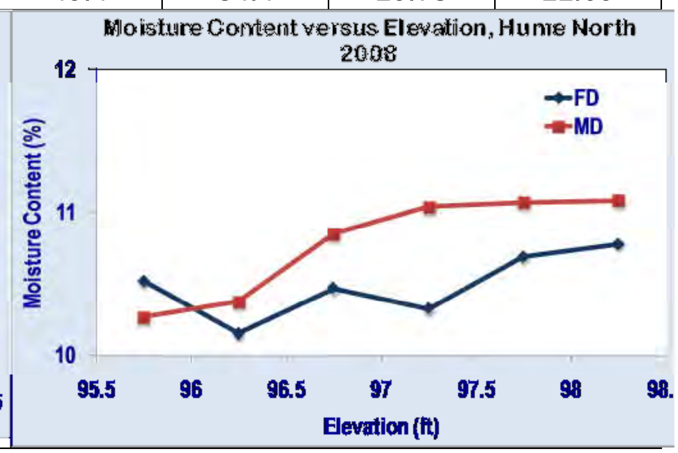


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 120c. Hume North, 2008, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
95.73	**98.26**	**100**		**48.0**		**10.34**	
95.69	**98.21**		**100**		**48.0**		**10.68**
95.69	**98.21**		**77***		**47.9**		**10.56**
95.5	96	16.3	14.9	49.7	47.1	10.52	10.27
96	96.5	45.0	30.2	47.9	46.4	10.15	10.37
96.5	97	29.0	31.7	48.1	48.3	10.47	10.85
97	97.5	6.3	15.8	44.9	49.3	10.32	11.04
97.5	98	2.5	5.4	45.1	50.6	10.69	11.07
98	98.5	1.0	2.1	49.4	54.4	10.78	11.09

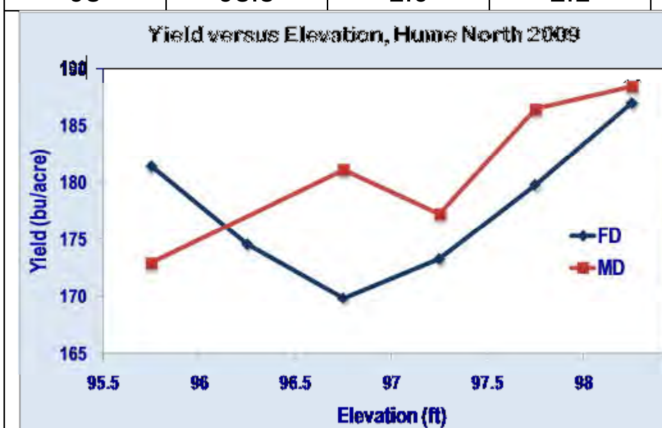


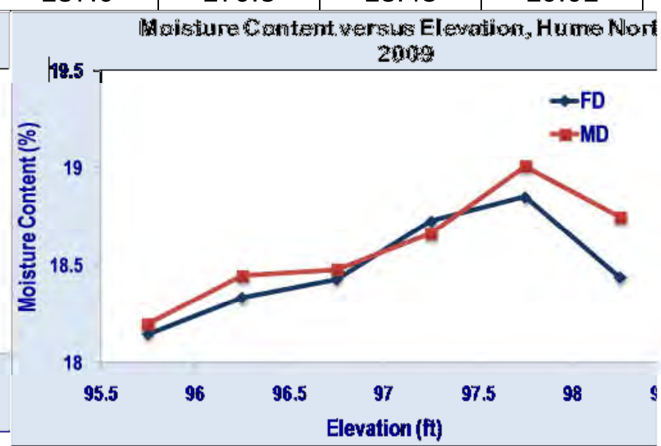


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 120d. Hume North, 2009, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
95.73	**98.26**	**100**		**174.6**		**18.38**	
95.69	**98.21**		**100**		**179.8**		**18.50**
95.69	**98.21**		**77***		**184.1**		**18.42**
95.5	96	16.3	14.9	181.4	172.9	18.15	18.20
96	96.5	45.0	30.2	174.6	181.1	18.33	18.20
96.5	97	29.0	31.7	169.8	177.2	18.43	18.45
97	97.5	6.3	15.8	173.3	186.4	18.73	18.48
97.5	98	2.5	5.4	179.7	188.4	18.85	18.66
98	98.5	1.0	2.1	187.0	179.8	18.43	19.01

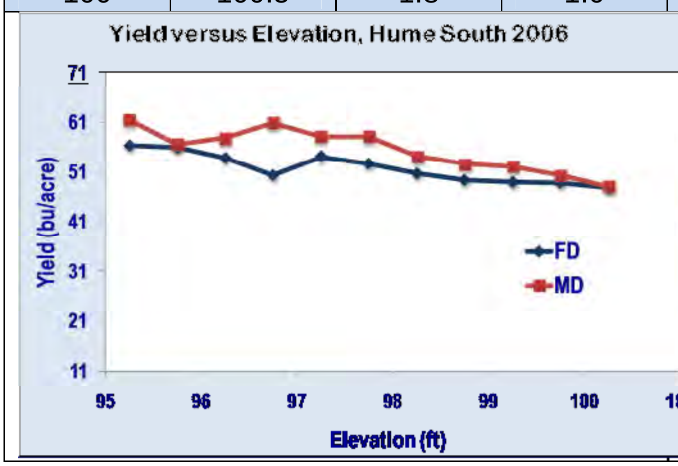


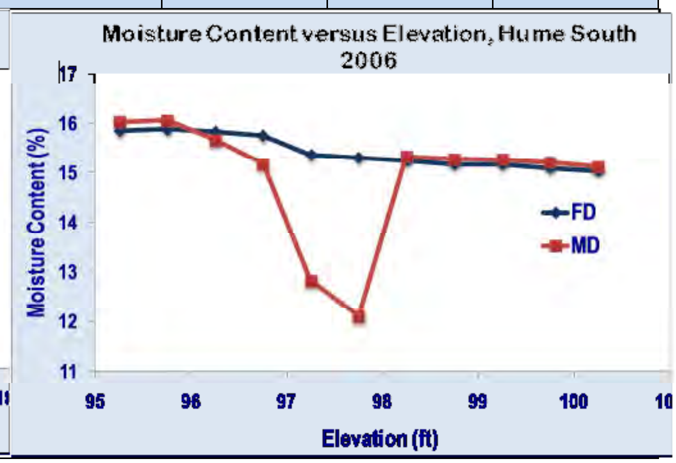


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 121a. Hume South, 2006, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	**Upper**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**
95.27	**100.35**	**100**		**53.7**		**15.77**	
95.09	**100.31**		**100**		**58.1**		**14.40**
95.09	**97**		**52***		**59.0**		**15.55**
95	95.5	5.7	1.2	56.3	61.4	15.85	16.03
95.5	96	29.8	8.9	55.9	56.5	15.88	16.06
96	96.5	26.8	19.3	53.8	57.8	15.83	15.66
96.5	97	15.7	22.4	50.2	60.8	15.75	15.18
97	97.5	7.0	30.7	54.0	58.1	15.36	12.83
97.5	98	4.0	9.1	52.5	58.0	15.31	12.11
98	98.5	3.0	2.4	50.6	54.1	15.25	15.33
98.5	99	2.8	1.9	49.2	52.5	15.17	15.28
99	99.5	2.2	1.9	48.8	52.0	15.16	15.27
99.5	100	1.7	1.4	48.7	50.2	15.08	15.21
100	100.5	1.8	1.0	47.7	48.0	15.03	15.12

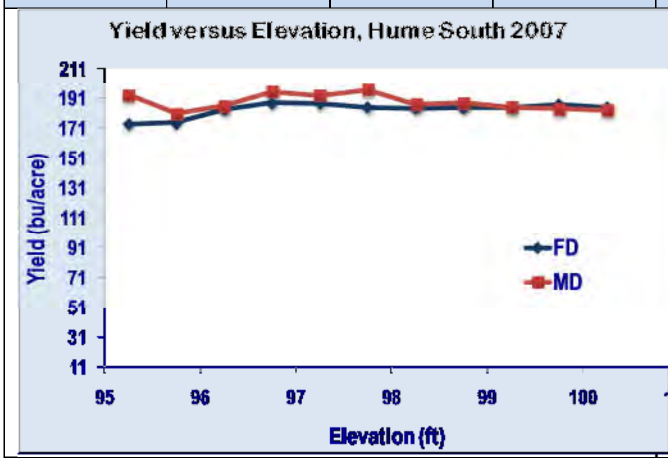


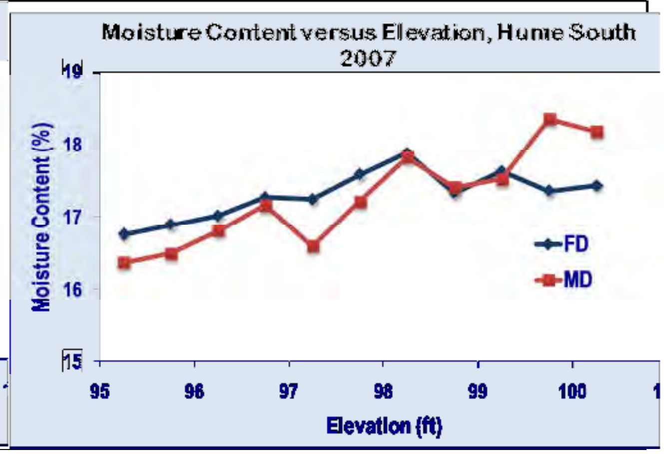


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 121b. Hume South, 2007, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
95.27	**100.35**	**100**		**182.3**		**17.17**	
95.09	**100.31**		**100**		**190.9**		**16.94**
95.09	**97**		**52***		**189.4**		**16.91**
95	95.5	5.7	1.2	173.7	26.9	16.75	16.36
95.5	96	29.8	8.9	174.8	30.2	16.88	16.49
96	96.5	26.8	19.3	183.4	27.4	17.01	16.80
96.5	97	15.7	22.4	187.8	12.0	17.27	17.16
97	97.5	7.0	30.7	187.4	21.8	17.24	16.59
97.5	98	4.0	9.1	184.8	16.3	17.58	17.21
98	98.5	3.0	2.4	184.2	19.4	17.88	17.82
98.5	99	2.8	1.9	184.5	22.4	17.33	17.41
99	99.5	2.2	1.9	184.7	21.9	17.62	17.52
99.5	100	1.7	1.4	186.8	24.8	17.35	18.35
100	100.5	1.8	1.0	184.7	28.4	17.43	18.18

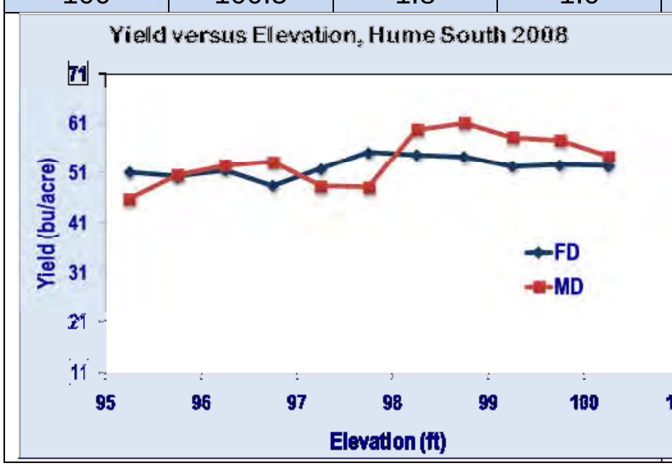


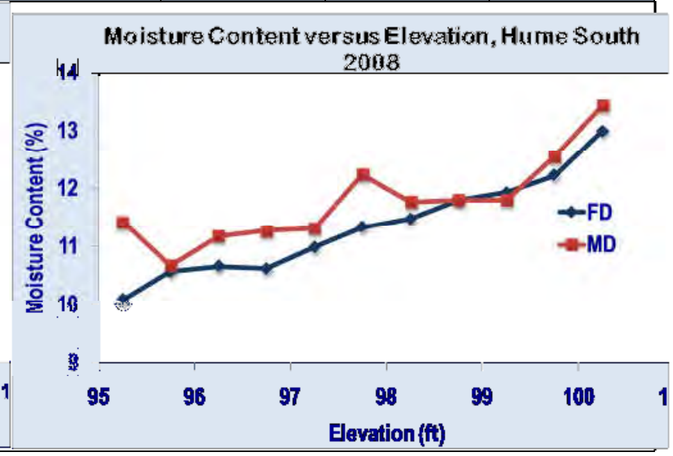


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 121c. Hume South, 2008, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
95.27	**100.35**	**100**		**51.2**		**10.84**	
95.09	**100.31**		**100**		**51.3**		**11.40**
95.09	**97**		**52***		**52.3**		**11.15**
95	95.5	5.7	1.2	51.0	45.7	10.09	11.42
95.5	96	29.8	8.9	50.2	50.5	10.57	10.67
96	96.5	26.8	19.3	51.5	52.4	10.66	11.17
96.5	97	15.7	22.4	48.4	53.1	10.61	11.27
97	97.5	7.0	30.7	51.7	48.3	10.98	11.32
97.5	98	4.0	9.1	55.1	48.1	11.33	12.24
98	98.5	3.0	2.4	54.6	59.7	11.47	11.77
98.5	99	2.8	1.9	54.2	61.0	11.80	11.80
99	99.5	2.2	1.9	52.3	58.1	11.92	11.80
99.5	100	1.7	1.4	52.5	57.5	12.22	12.55
100	100.5	1.8	1.0	52.3	54.3	12.99	13.43

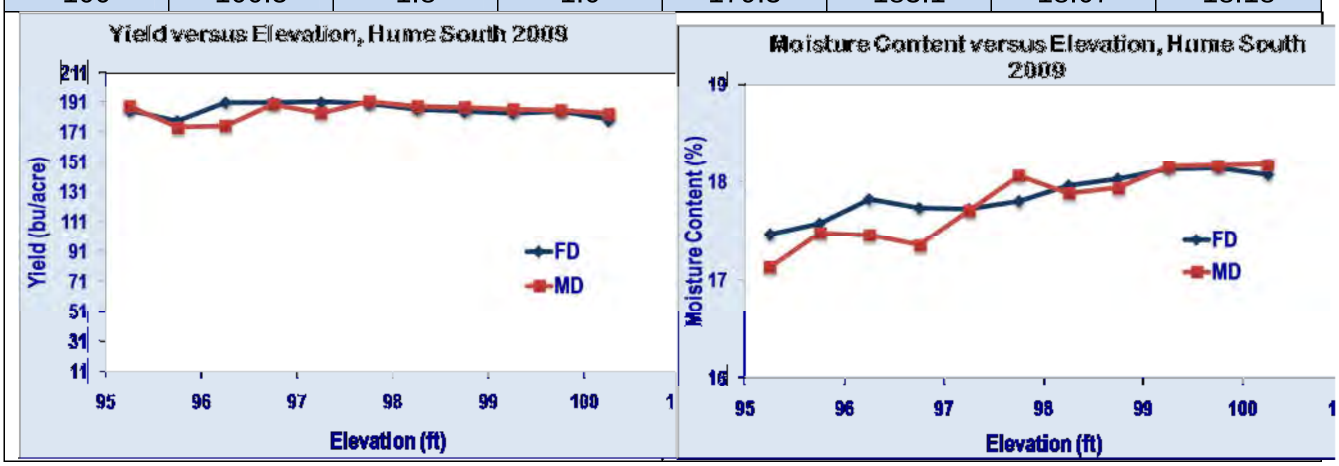




*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 121d. Hume South, 2009, crop yields.

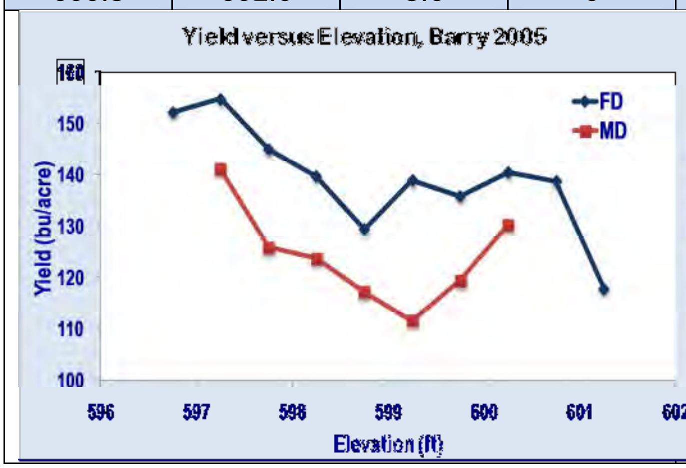
Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
95.27	**100.35**	**100**		**186.7**		**17.81**	
95.09	**100.31**		**100**		**183.8**		**17.65**
95.09	**97**		**52***		**181.6**		**17.43**
95	95.5	5.7	1.2	185.2	188.2	17.46	17.13
95.5	96	29.8	8.9	178.4	174.0	17.57	17.47
96	96.5	26.8	19.3	190.7	175.0	17.82	17.45
96.5	97	15.7	22.4	190.6	189.3	17.73	17.35
97	97.5	7.0	30.7	191.1	183.6	17.72	17.71
97.5	98	4.0	9.1	189.7	191.4	17.80	18.06
98	98.5	3.0	2.4	186.1	188.2	17.96	17.88
98.5	99	2.8	1.9	184.4	187.3	18.03	17.94
99	99.5	2.2	1.9	183.6	186.0	18.13	18.15
99.5	100	1.7	1.4	184.3	185.6	18.14	18.17
100	100.5	1.8	1.0	179.3	183.1	18.07	18.18

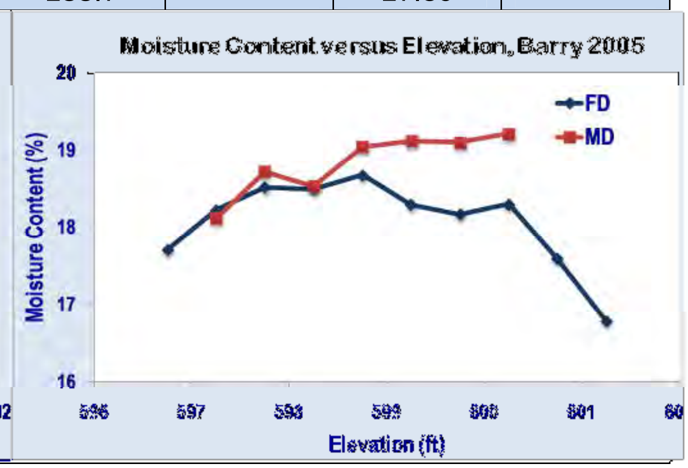


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 122a. Barry, 2005, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	**Upper**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**
596.9	**605.4**	**100**		**140.6**		**18.44**	
596.94	**600.39**		**100**		**121.0**		**18.93**
596.94	**599**		**57***		**122.9**		**18.75**
596.5	597.0	4.5	0	152.1		17.70	
597.0	597.5	15.4	4.5	154.8	141.1	18.22	18.11
597.5	598.0	14.9	11.3	144.9	125.8	18.51	18.71
598.0	598.5	12.6	20.7	139.8	123.7	18.49	18.52
598.5	599.0	9.7	20.2	129.3	117.2	18.67	19.04
599.0	599.5	7.3	20.7	138.9	111.5	18.28	19.11
599.5	600.0	7.9	16.8	135.9	119.4	18.16	19.09
600.0	600.5	7.7	5.7	140.5	130.3	18.29	19.21
600.5	601.0	5.6	0	138.7		17.59	

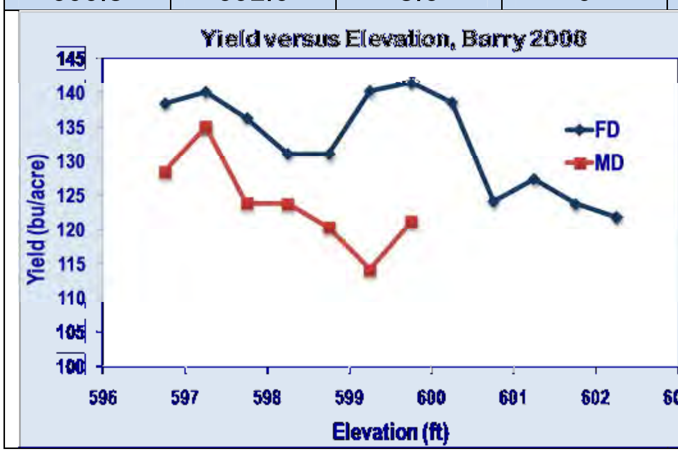


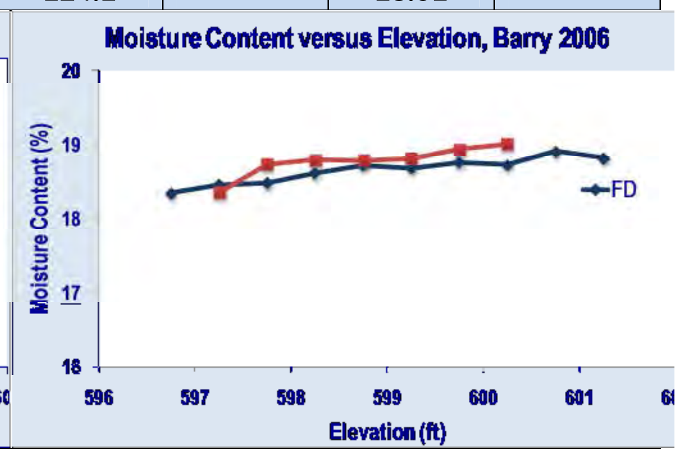


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 122b. Barry, 2006, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
596.9	**605.4**	**100**		**135.7**		**18.89**	
596.94	**600.39**		**100**		**120.3**		**18.95**
596.94	**599**		**57***		**123.5**		**18.79**
596.5	597.0	4.5	0	138.4	128.4	18.34	
597.0	597.5	15.4	4.5	140.1	135.0	18.46	18.35
597.5	598.0	14.9	11.3	136.3	135.0	18.48	18.73
598.0	598.5	12.6	20.7	131.0	123.8	18.61	18.79
598.5	599.0	9.7	20.2	131.0	123.8	18.72	18.78
599.0	599.5	7.3	20.7	140.2	120.2	18.68	18.81
599.5	600.0	7.9	16.8	141.4	114.1	18.75	18.93
600.0	600.5	7.7	5.7	138.5	121.1	18.72	19.01
600.5	601.0	5.6	0	124.1		18.91	

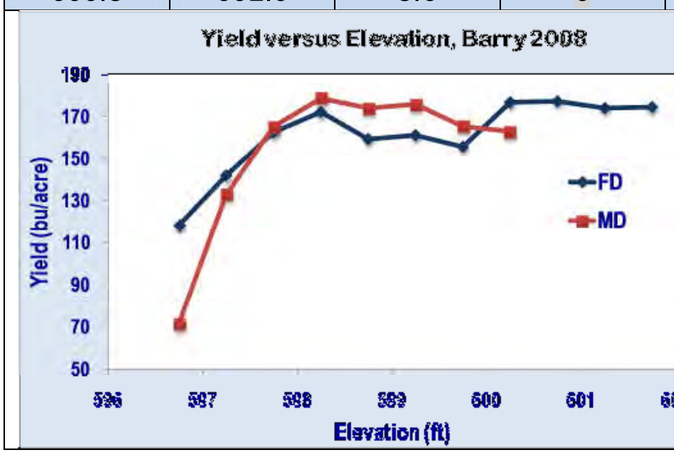


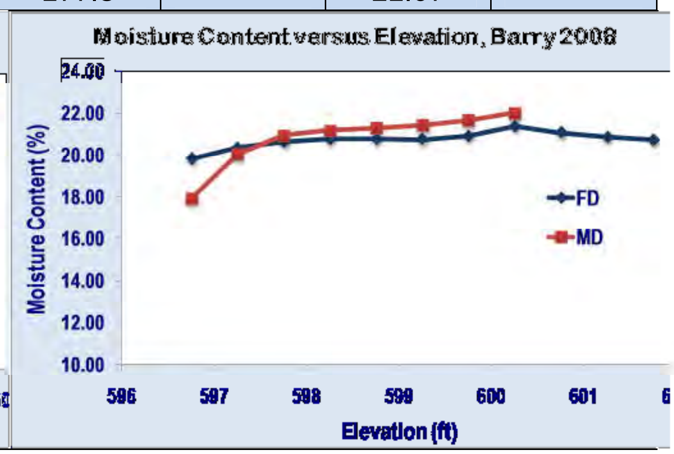


*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 122c. Barry, 2008, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	**Upper**	**CD**	**MD**	**CD**	**MD**	**CD**	**MD**
596.9	**605.4**	**100**		**160.3**		**20.10**	
596.94	**600.39**		**100**		**166.49**		**21.36**
596.94	**599**		**57***		**168.0**		**21.12**
596.5	597.0	4.5	0	118.0		19.81	
597.0	597.5	15.4	4.5	141.7	132.9	20.36	17.92
597.5	598.0	14.9	11.3	162.3	165.0	20.63	20.05
598.0	598.5	12.6	20.7	171.8	178.5	20.78	20.95
598.5	599.0	9.7	20.2	159.2	173.8	20.76	21.18
599.0	599.5	7.3	20.7	161.2	175.6	20.75	21.29
599.5	600.0	7.9	16.8	155.7	165.3	20.91	21.43
600.0	600.5	7.7	5.7	176.5	162.8	21.38	21.67
600.5	601.0	5.6	0	177.3		21.07	





*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Figure 122d. Barry, 2009, crop yields.

Elevation (ft)		Percent Field Area (%)		Yield (bushels/acre)		Moisture Content (%)	
Lower	Upper	CD	MD	CD	MD	CD	MD
596.9	**605.4**	**100**					
596.94	**600.39**		**100**				
596.94	**599**		**57***				
596.5	597.0	4.5	0				
597.0	597.5	15.4	4.5				
597.5	598.0	14.9	11.3				
598.0	598.5	12.6	20.7				
598.5	599.0	9.7	20.2				
599.0	599.5	7.3	20.7				
599.5	600.0	7.9	16.8				
600.0	600.5	7.7	5.7				
600.5	601.0	5.6	0				

*: Area of field influenced by control structure (elevation less than 12 inches higher than outlet elevation)

Table 36. Enfield, 2005-2009.

Year	Yield (bushels/acre)		Moisture Content (%)	
	CD	MD	CD	MD
2005	**48.3**	**59.1**	**9.56**	**10.00**
2006	**197.7**	**192.6**	**14.05**	**13.99**
2007	**50.5**	**60.8**	**7.91**	**8.06**
2008	**194.8**	**186.2**	**13.99**	**14.72**
2009	**54.7**	**53.5**	**13.7**	**12.6**

COSTS OF INSTALLATION

Estimated cost of installation by size of main is outlined in the following table. These costs are just an estimate and cost of materials; installation and labor may vary from area to area. Generally, DWM areas should be designed to control approximately 20 acres. Using the table below, per-acre costs for a new installation would start at $65/acre for 6-inch main and increase to $88/acre for a retrofit installation on 12-inch main. Because these structures are eligible for depreciation that should be cost factored over 15 years. If the cost is factored on 20 acres over 15 years at 6% interest, the annual cost per acre for a 6-inch main would be $6.73/year and for a 12-inch main would be $9.08/year. The initial cost for this practice may be reduced if the producer applies for cost-share funding under the USDA EQIP program.

To cover the expense of the control structures for this management practice, using $4.00/bu. corn, it would take an additional 1.68 bushels per acre in yield for a 6-inch main and 2.27 additional bushels for a 12-inch main. Some of the costs could also be offset using investment tax credits or taxable asset depreciation.

Table 37. Estimated costs of drainage water management system installation.

Size of Tile Main	**6”**	**8”**	**10”**	**12”**
Control Structure	$ 617.00	$ 715.00	$ 803.00	$ 1002.00
Anti-seep Collar	$ 55.00	$ 55.00	$ 55.00	$ 55.00
20’ of DW Non-perf	$ 36.00	$ 58.00	$ 78.00	$ 107.00
Installation Costs	$ 450.00	$ 450.00	$ 450.00	$ 450.00
Subtotal	**$ 1,158.00**	**$ 1,278.00**	**$ 1,386.00**	**$ 1,614.00**
Mobilization Costs	$ 150.00	$ 150.00	$ 150.00	$ 150.00
Total if Retrofit Only	**$ 1,308.00**	**$ 1,428.00**	**$ 1,536.00**	**$ 1,764.00**

OUTREACH & COMMUNICATION NETWORK

Outreach is a vital part not only of the DWM CIG project, but also of exploring and promoting drainage water management in the Midwest. Outreach under the CIG demonstration project allowed ADMC and our cooperators to display, demonstrate and discuss DWM technology with farmers, researchers, NRCS personnel, drainage contractors, extension agents, state and local agency representatives and environmental group leaders. Just as important as outbound information was the inbound information we received during this process – the questions, concerns and suggestions we received from stakeholders who were exploring these systems through our outreach efforts.

On the following pages, we outline the outreach components of the project.

Indiana

Table 38. Activities to share information from drainage water management project.

Presentation Type	**Date**	**Audience** (all numbers are approximate)
Indiana LICA Annual Convention	January 25, 2007	50 drainage contractors
Bi-County Soils Program, Delphi Indiana	March 1, 2007	60 farmers
CTIC tour: presentation on controlled drainage at Crawfordsville site	June 21, 2007	60 farmers
Drainage field day at Northeast Purdue Agriculture Center	August 10-11, 2007	50 contractors and farmers
Web presentation on agricultural drainage management	Feb 27, 2008	35 conservation staff from Indiana and Ohio
Discussion of yield data collection at Agricultural Drainage Management Systems Task Force	April 1, 2008	40 agency staff and researchers
Presentation at Indiana Water Resources Association, Bloomington Indiana	May 15, 2008	100 water professionals
International Drainage Workshop, Helsinki, Finland	July 9, 2008	100 international participants
Bi-state No-Till Day, Cayuga, Indiana.	July 30, 2008	120 farmers
Field Day at Reynolds and Wolcott sites	Sept 2, 2008	40 farmers
Presentation at Overholt Drainage School, Wooster, Ohio	March 26, 2009	30 farmers and drainage contractors
Web presentation on drainage water management	April 9, 2009	Watershed Academy participants
Denitrification Conference, Newport, Rhode Island	May 12, 2009	100 scientists
Purdue/ LICA (Land Improvement Contractors Assoc.) Field Day on drainage systems, wetlands, buffers, held at SEPAC.	August 14-15, 2009	100 farmers and contractors
Davis-PAC Field Day presentation	August 18, 2009	150 farmers
Iowa-Minnesota Drainage Research Forum	November 10, 2009	???
Shelby County Conservation Field Day, drainage and water quality	Sept 3, 2009	100 farmers, extension agents, conservation agency personnel?
Drainage Water Management Field Day, Montgomery County	Sept. 8, 2009	50 farmers, extension agents, conservation agency personnel?
Additional talks (8) on drainage and water quality, which includes some discussion of drainage water management	2007-2009	700 farmers, conservation agencies, drainage contractors, crop consultants, extension

Publications

1. Carter, B., S. Brouder, and E.J. Kladivko. 2006. Effect of controlled drainage on corn and soybean yields and corn crop N balance. Agron.Abs. (CD-ROM)
2. Frankenberger, J.R., E. Kladivko, R. Adeuya, L. Bowling, B. Carter, S. Brouder, J. Lowenberg-De-Boer, and J. Brown. 2006. Drainage water management impacts on nitrate load, soil quality, and crop yield. Proc. Innovations in Reducing Nonpoint Source Pollution Conf., Nov. 28-30, Indianapolis, Indiana.
3. Carter, B., S. Brouder, and E.J. Kladivko. 2007. Effect of controlled drainage on corn and soybean yields and corn crop N balance. Agron.Abs. (CD-ROM)
4. Frankenberger, J., E. Kladivko, R. Adeuya, N. Utt, L. Bowling, and B. Carter. 2008. Determining the hydrologic impacts of drainage water management in Indiana, USA. Pp. 134-141 in Proc. 10th International Drainage Workshop of ICID Working Group on Drainage, July 6-11, Helsinki, Finland/Tallinn, Estonia.
5. Frankenberger, J., E. Kladivko, G. Sands, D. Jaynes, N. Fausey, M. Helmers, R. Cooke, J. Strock, K. Nelson, L. Brown, 2006. Questions and Answers About Drainage Water Management for the Midwest. WQ-44. 8 p.
6. Adeuya, R., 2009. The Impacts of Drainage Water Management on Water Table Depth, Drain Flow, and Yield. Purdue University Ph.D. Dissertation.

Publications planned

1. Delbecq, B., R. Florax, and J. Lowenberg-DeBoer. The impact of drainage management technology in agriculture: A spatial panel data model. In manuscript form, to be submitted to Agron. J. in spring 2010.
2. Adeuya, R. K. , J.R. Frankenberger, N.J. Utt, B.A. Carter, E. J. Kladivko, L.C. Bowling, and S.M. Brouder. The impact of drainage water management on water table depth and drain flow for farms in Indiana. In manuscript form, to be submitted to Agricultural Water Management in Spring 2010.
3. Utt, N., 2010. Impacts of drainage water management on plant and soil nutrient levels, soil physical properties, and nutrient loading to surface waters. Purdue University M.S. Thesis.

Iowa

Table 39. Activities to share information from drainage water management project.

Publication Type	Date	Audience (who, how many)
Oral presentation on Drainage Water Management	30 Dec, 2009	North-Central Iowa Certified Crop Advisors, 30 attendees
Oral presentation on Iowa CIG	10 Nov, 2009	MN-IA Drainage Forum, 100 state regulators and researchers
Oral presentation to the State Soil Conservation Committee	1 Oct, 2009	10 committee members
Oral presentation on Drainage Water Management and Bioreactors	28 July, 2009	NRCS personnel in Iowa, 40 attendees
Oral presentation “Saturated Buffers and Nutrient Reduction for Tile-Drained Cropland” at Emerging Nitrogen Reduction Practices for Tile-Drained Cropland Workshop	26 June, 2009	60, state regulators, researchers
Toured across central Iowa explaining tile drainage and our drainage water management research	9 Apr, 2009	Sally Collins, Director Ecosystem Services and Markets, USDA, Bill Northey, Iowa Secretary of Agriculture; Dean Lemke, Iowa Dept. of Ag & Land Stewardship; Richard Sims, NRCS State Conservationist; Alex Echols, Sand County Foundation; Mark Gibson, Hach Company; Roger Wolf, Iowa Soybean Association; Tim Recker, Iowa Corn Growers Association; Leonard Binstock and Charlie Schafer, Agricultural Drainage Management Coalition
Oral presentation to Iowa drainage school	10 Sept, 2008	35 drainage contractors
Oral presentation “Updates on Current Science of Nutrient Flows and Conservation Actions in Iowa” at the Hypoxia in the Gulf of Mexico: Implications and Strategies for Iowa	16 Oct, 2008	250, state regulators, researchers
Oral presentation on Drainage Water Management	20 August, 2008	25 NRCS personnel
Oral presentation on Drainage Water Management	6 August, 2008	135 local producers in central Iowa
Oral presentation on Drainage Water Management	26 June, 2008	50 local producers in southeast Iowa
Presented “Walnut Potential Water Quality Impact of Drainage Water Management in the Midwest Cornbelt”	2 July, 2008	100 researchers
Oral presentation on drainage water management at the	16 July, 2007	Boone River Watershed Project Review
Oral presentation on drainage water management	13 March, 2007	Drainage workshop in north-central Iowa – 20 attendees

Ohio

Table 40. Activities to share information from drainage water management project.

Publication Type	Date	Audience (who, how many)
Drainmod NII Workshop		17
Over 50 presentations	2007-2010	Over 3500
Overholt Drainage School DWM session	2007	50+
Overholt Drainage School DWM session	2008	50+
Overholt Drainage School DWM session	2009	50+
Overholt Drainage School DWM session	2010	85+
5 presentations at state, national and international professional meetings- US and China		Over 350

Shang, Y., Brown, L.C., Fausey, N.R. and Yioussef, M.A., 2009.Evaluation of DRAINMOD-N2 for Ohio Conditions. ASABE Paper No. 090011. Presented at 2009 International Meeting of ASABE. ASAE St. Joseph, MI. 7 pp.

Cooke, R.A., G.R. Sands and L.C. Brown. 2008. Drainage Water Management: A practice for reducing nitrate loads from subsurface drainage systems. Chapter 2, Pgs 19-27 In: Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. ASABE Publication 913C0308. 212 pp.

Frankenberger, J., E. Kladivko, G. Sands, D. Jaynes, N. Fausey, M. Helmers, R. Cooke, J. Strock, K. Nelson and L. Brown. 2007. Questions and Answers about Drainage Water Management for the Midwest. Purdue University Bulletin WQ-44. 8 Pgs.

Minnesota

(Conservation Drainage Outreach and Education Summary)

- From October 2007 to October 2009, the University of Minnesota, Minnesota Department of Agriculture, and ADMC hosted, participated in, and presented at conservation drainage workshops, symposiums, annual conferences, and field days.
- These events were attended by over 2,200 people at thirty-two events. (See below)
- More than 2,900 copies of DWM publications were distributed, and more than 1600 visits were made to ADFA conservation drainage web pages.

Table 41. Activities to share information from drainage water management project.

Field days, tours & workshops	Date	Audience
Clean Water Council Field Tour: NGO's, Farm Organizations, State and Federal Agencies, Regional and Local Conservation Groups. St. Peter Mn	October 2007	70 participants
Mn Watershed Districts Association Annual Mtg and Trade Show: Drainage Workshop Alexandria Mn	November 2007	130 participants
Mn Soil and Water Conservation Annual Convention: Rochester Mn	December, 2007	200 participants
Mn Land Improvement Contractors: Annual Conference: Owatonna Mn	January, 2008	45 participants
Mn Soybean Growers: Annual Conference. Morton Mn	January, 2008	80 participants
Mn Corn Growers: Annual Conference. Bloomington Mn	January, 2008	120 participants
Ag Rural Water Mgmt Meeting. Shakopee Mn	January, 2008	35 participants
University of Minnesota Drainage Conference: Willmar Mn	March, 2008	65 participants
Zumbro Watershed Partnership Meeting: Oronoco Mn	March, 2008	20 participants (bad weather)
Conservation Drainage Symposium / Workshop: Clean Up Our River Environment. Montivideo Mn.	April, 2008	50 participants
Conservation Drainage Symposium / Workshop: New Ulm Mn. Mn Sportsmens Coalition	April, 2008	40 participants
Conservation Drainage Symposium / Workshop: Friends of the Mn River Blmgtn Mn.	April, 2008	10 participants (bad weather)
Project Coordination Team Tour: CWA Section 319 Executive Committee	May, 2008	10 participants (bad weather)
Farmfest: Morton Mn	August, 2008	155 participants
Agroecology Summit: Windom Mn	August, 2008	60 participants
Tile Line Smoke Demo: Waseca Mn	August, 2008	25 participants
Heron Lake Watershed District Bus Tour – Controlled drainage,	September, 2008	20 participants
Field Day – Ryan Miller – UofM-Extension, Clarks Grove Mn	August, 2008	75 participants
Drainage Water Management Workshop: Lamberton, MN (UofM—SWROC)	August, 2008	25 participants
Mn Watershed Districts Association Annual Mtg and Trade Show: Drainage Workshop Alexandria Mn	November, 2008	180 participants
Mn Soil and Water Conservation Annual Convention: St. Paul Mn	December, 2008	150 participants
Drainage Work Group Eagan Mn	February, 2009	35 participants

Table 41 (continued). Activities to share information from drainage water management project.

Field days, tours & workshops	Date	Audience
Mn Land Improvement Contractors: Annual Conference: Owatonna Mn.	February, 2009	55 participants
Mn Soybean Growers: Annual Conference. Morton Mn	January, 2009	80 participants
Mn Corn Growers: Annual Conference. Morton Mn	January, 2009	190 participants
University of Minnesota Drainage Conference: Willmar Mn	March, 2009	25 participants
Conservation Drainage Symposium / Workshop: Brown Nicollet Cottonwood Water Quality Brd, and Clean Up Our River Environment. Henderson Mn	March, 2009	25 participants
Conservation Drainage Symposium / Workshop: Granite Falls Mn. Clean up the River Environment, and the Mn Sportsmens Coalition	March, 2009	25 participants
Future of Drainage Workshop Owatonna Mn.	March, 2009	30 participants
Ag Rural Water Mgmt Meeting. St. Peter Mn	June, 2009	35 participants
Farmfest: Morton Mn.	August, 2009	90 participants
Agroecology Summit: Windom Mn.	August, 2009	60 participants
Heron Lake Watershed District – Controlled drainage,	August, 2009	25 participants
Drainage Work Group Eagan Mn	August, 2009	35 participants
Mn River Basin Professional Training – Shannon Fisher MSU –WRC Morton Mn.	October, 2009	75 participants

Illinois

Table 42. Activities to share information from drainage water management project.

Presentation Type	Date	Audience (all numbers are approximate)
Illinois/Indiana Extension Workshop, Covington, Indiana	December 6, 2006	50 farmers and contractors
Iowa LICA Annual Convention, Des Moines, Iowa	January 8, 2007	30 farmers and contractors
Illinois LICA Annual Convention, Moline, Illinois	January 19, 2007	30 drainage contractors
Illinois Extension Workshop, Hillsboro, Illinois	February 6, 2007	50 farmers and contractors
Tour with French producers wanting to adopt DWM, Jacksonville, Illinois	June 12, 2007	3 farmers
Illinois Extension Workshop, Ottawa Illinois	June 14, 2007	20 farmers
Bureau County Agronomy Day, Princeton, Illinois	August 14, 2007	30 farmers
Indiana Crop Protection Conference, Indianapolis	December 18, 2007	50 contractors and farmers
Illinois LICA Annual Convention, Moline, Illinois	January 18, 2008	30 drainage contractors
Land Improvement Contractors of Ontario Annual Meeting, London, Ontario	January 24, 2008	70 drainage contractors
ILICA sponsored Drainage Workshop, Kewanee, IL	February 5, 2008	30 producers
ILICA sponsored Drainage Workshop, Champaign, IL	February 7, 2008	50 producers
ILICA sponsored Drainage Workshop, Litchfield, IL	February 12, 2008	70 producers
ILICA sponsored Drainage Workshop, Centralia, IL	February 13, 2008	30 producers
ILICA Drainage and DWM Certification Workshop, Springfield, IL	February 18, 2008	45 contractors
NRCS sponsored DWM Workshop, Champaign, IL	June, 2008	30 contractors
AWMC sponsored Drainage Day	September 4, 2008	60 participants
Extension sponsored Crop Protection Workshops in Jacksonville, Illinois	January 28, 2009	150 participants
Extension sponsored Crop Protection Workshops in Rend Lake, Illinois	January 29, 2009	100 participants
Extension sponsored Crop Protection Workshops in Malta, Illinois	February 5, 2009	60 participants
Illinois Association of Drainage Districts (IADD) Meeting, Bloomington, IL	January 21, 2010	70 participants
Indiana LICA Annual Meeting, Indianapolis	January 28, 2010	30 contractors

Agricultural Drainage Management Coalition

Table 43. Activities to share information from drainage water management project.

Presentations	Date	Audience (all numbers are approximate)
Plastic Pipe Institute Annual Meeting	03/22/07	75
North Carolina	04/19/07	60
Wilmont Field Day	06/20/07	55
Dundas Field Day	06/21/07	70
ACWA, IA	06/22/07	30
MN LICA	06/23/07	14
Martin County Field Day	07/09/07	90
LICA Convention Omaha, NE	07/19/07	40
SW Conservation Society Meeting	07/25/07	120
EPA Meeting Austin, TX	08/27/07	65
Plastic Pipe Institute semi annual meeting	09/07/08	75
MN/ IA Drainage Forum	11/27/07	140
MN Farm Management	11/28/07	70
MN Assoc Water Districts	11/29/07	200
IA Soybean & Pioneer Seed	12/21/07	
IA reg	01/06/08	200
MN Corn Growers	01/11/08	250
MN Soybean Growers	01/14/08	140
IL LICA annual meeting	01/17/08	40
MN LICA Convention	01/20/08	80
Redwood Falls, MN	01/22/08	30
Willmar, MN	01/23/08	
IA State University IA Water Conference	02/07/08	45
Wingert Survey	03/09/08	12
Linn County Soil Water- Iowa	03/14/08	40
Rinke Noonan Drainage Seminar	03/26/08	??
Plastic Pipe Institute annual meeting	04/18/08	75
The Nature Conservancy		250
Windom Farm Fest	08/04/08	
MN Farm Fest	08/07/08	
Lamberton Contractor Training	08/14/08	20
Windom Field Day	08/15/08	120
IL Farm Forum Hume, IL	08/27/08	50
OH Farm Forum	09/01/08	
IN Farm Forum	09/02/08	
Iowa Farm Fest	09/10/08	150
MN Water Resources Coalition	09/19/08	24
MN Farm Bureau	10/15/08	20
Plastic Pipe Institute semi annual meeting	10/24/08	60
IA MN Drainage Forum	12/02/08	

Table 43 (continued). Activities to share information from drainage water management project.

Presentations	Date	Audience (all numbers are approximate)
MN Corn Growers	01/09/09	300
IA LICA Convention	01/11/09	200
IL LICA annual meeting	01/16/09	150
MN LICA Convention	01/18/09	80
Radio Interview	02/03/09	
Tom Bumen Algona, IA	02/06/09	4
National LICA Nashville, TN	02/11/09	100
MN Drainage Course	03/10/09	40
DWM presentation Henderson, MN	03/18/09	30
DWM presentation Granite Falls, MN	03/19/09	70
DWM presentation Farm Show	03/20/09	80
Sangamon Cty SWCD Meeting	03/26/09	50
DWM presentation Mankato, MN	04/07/09	110
Plastic Pipe Institute annual meeting	04/08/09	75
IA Group & Stanhope Forum	04/09/09	30
Realtors Institute	04/29/09	
St. Peter MN	06/18/09	
MN NRCS Tech Meeting	06/30/09	
WCA Rules Hearing		
DWM training Des Moines, IA	07/14/09	100
Farm Fest Booth	08/05/09	
Windom Field Day	08/21/09	150
IL Farm Forum- Hume, IL	08/27/09	40
IA Farm Forum- Crawfordsville, IA	08/28/09	30
IN Farm Forum- Crawfordsville, IN	09/08/09	50
OH Farm Forum- Lakeview, OH	09/09/09	35
Hypoxia Meeting Des Moines, IA	09/22/09	
MN River Basin	10/01/09	
Plastic Pipe Institute semi annual meeting	10/11/09	60
ADMS/ADMC Meeting	10/13/09	90
IA/ MN Drainage Forum	11/10/09	
Science to Solutions Workshop	12/09/09	
IA LICA Meeting	01/10/10	
MN LICA Convention	01/17/10	150
Radio Interview KDHL	02/01/10	
National LICA Convention Arizona	02/19/10	
Heron Lake Watershed	02/25/10	
Wulf Tiling- Hancock, MN	02/26/10	
ARS Water Showcase- St. Louis, MO	03/01/10	250
Dodge County	03/11/10	
Larson Tiling- Dawson, MN	03/24/10	

Preparing articles and literature for the outreach effort, the Conservation Technology Information Center (CTIC) interviewed a large number of sources for firsthand insight on drainage water management. Those sources are listed below:

Researchers/USDA Officials

Don Pitts, USDA-NRCS, Champaign, IL

Richard Cooke, University of Illinois

Matt Helmers, Iowa State University

Gary Sands, University of Minnesota

Jeff Strock, University of Minnesota

Craig Schrader, University of Minnesota

Mark Dittrich, Minnesota Department of Agriculture

Larry Brown, Ohio State University

Norm Fausey, USDA-ARS, Columbus, OH

Eileen Kladivko, Purdue

Jane Frankenberger, Purdue

Nathan Utt, Purdue

Doug Toews, USDA-NRCS, HQ

Mike Sullivan, USDA-NRCS, Little Rock, AR

Carl Lucero, USDA Office of Ecosystem Services and Markets, DC

Drainage Industry Representatives/Contractors

Charlie Schafer, AgriDrain/ADMC

Todd Redlin, FRATCO, Francisville, IN

Chris Smidler, West Central Water Management, Francisville, IN

Andy Nickel, Nickel Construction, Mountain Lake, MN

Kevin Ellingson, Ellingson Drainage, West Concord, MN

Rob Wood, Wood Water Management, North Salem, IN

Growers

Tony Thompson, Windom, MN

Dirk Fleck, Reynolds, IN

Doug Mills, Crawfordsville, IN

Gary Overmeyer, IN

Nathan Rettig, Napoleon, OH

Other Sources

Dusty Hall, Miami Conservancy District, Dayton, OH

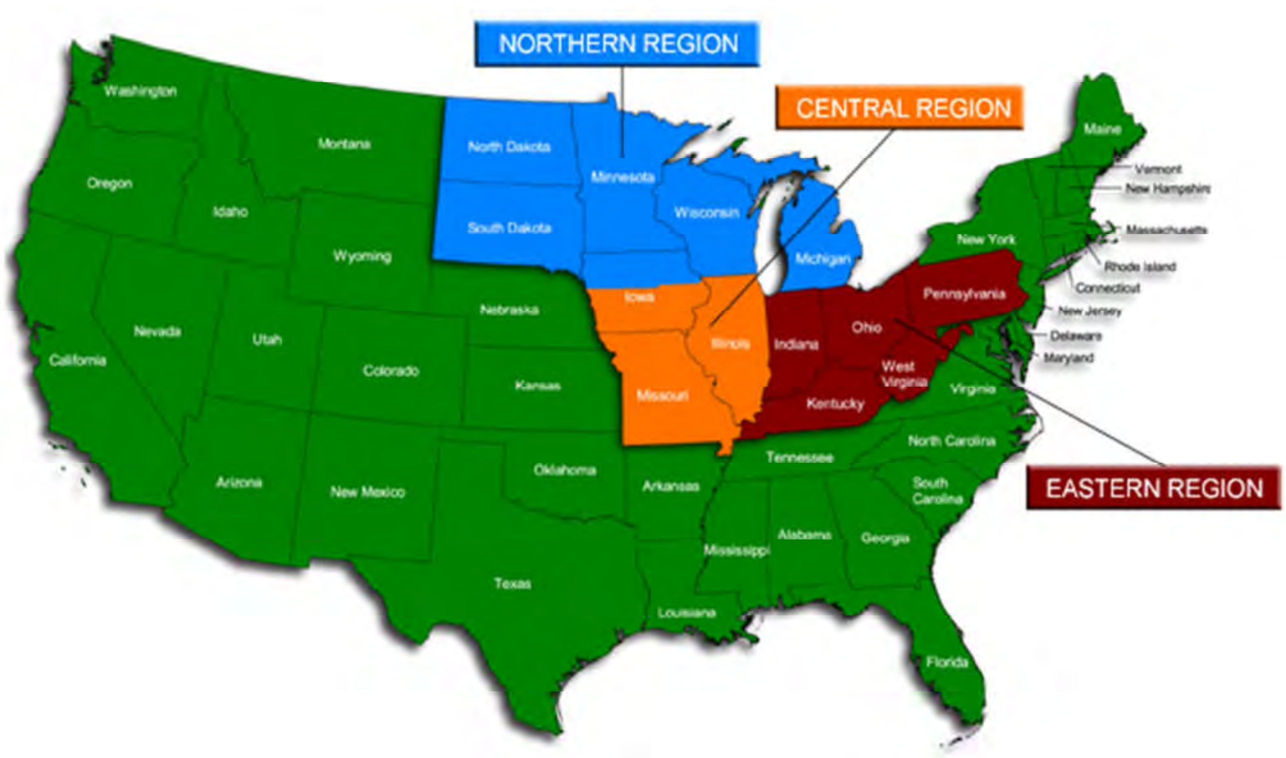
Jason Bruns, Shelby SWCD, Sydney, OH

John Kessler, Ohio Department of Agriculture

POTENTIAL FOR TRANSFERABILTY OF RESULTS

The lessons learned and questions raised during this CIG project provide a strong foundation for applying drainage water management – and accruing the benefits of the practice – on millions of acres throughout the upper Mississippi River watershed. In the state-by-state discussion below, we explore the land area that could accommodate DWM.

Figure 123. DWM Regional Application Map



Indiana

An estimate of drained acres in Indiana with various slopes was made using the following assumptions:

- Tile drained land was assumed to be cropland with soils in the following three drainage classes: somewhat poorly, poorly, and very poorly drained. STATSGO generalized soils information was used.
- Slopes were calculated from the National Elevation Dataset, which has a 30-meter resolution. These are land slopes, as we have no information about tile system grade.

Using these assumptions, total tile drained was estimated to be about 7 million acres, or 30.2% of the state. This compares to about 5.8 million acres that are also in cropland and are assumed to be well-enough drained to not require tile drainage. Our rough opinion is that the estimate of percentage drained using this method is probably a little low, so the numbers in Table 44 may also be low. However they are the best we have available. (Note we added a column for slopes less than 0.5%, and combined 1-to-1.5% and 1.5-to-2%.)

Table 44. Quantity of Indiana drained acres by percentage of grade.

Total Acres in IN= 23 million acres total, approximately 7 million drained acres	**<0.5% grade**	**0.5- 1.0% grade**	**1.0- 2% grade**	**> 2% grade**
Number of acres	2.27 million	2.28 million	1.43 million	1.06 million

Iowa

Table 45. Quantity of Iowa drained acres by percentage of grade.

Total Acres in IA=__ 36,004,620__	**0.5- 1.0% grade**	**1.0- 1.5% grade**	**1.5- 2.0% grade**	**2.0- 2.5% grade**
Number of acres	1,730,000	1,540,000	1,540,000	

Ohio

Data not provided.

Minnesota

The attached map titled "Transferability of Managed Drainage in Minnesota" uses Soils and Land Surfaces of Minnesota Layer by J.F. Cummins and D.F. Grigal, and Common Resource Areas of Minnesota via USDA - NRCS.

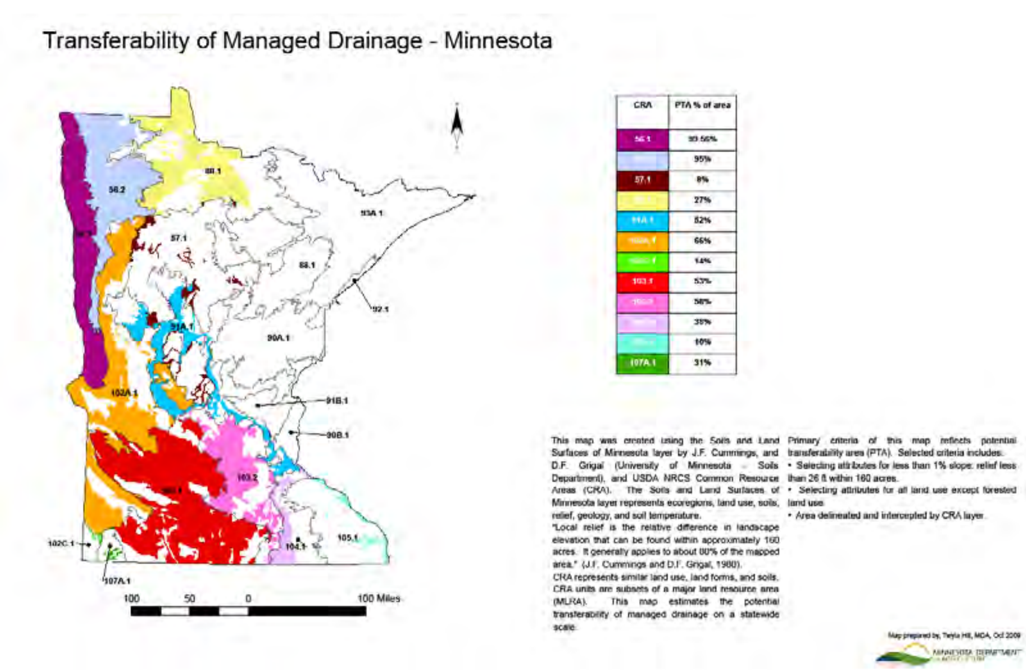
The Soils and Land Surfaces of Minnesota layer represents regions based on historical vegetation, soils, local relief, geology and soil temperature. Local relief is defined as the relative difference in landscape elevation that can be found within approximately 160 acres. It generally applies to about 80% of the mapped area (1980, J.F. Cummins and D.F. Grigal).

Common Resource Areas represent areas of land that are similar in land use, land forms, soils, etc. Primary criteria utilized:

- Relief less than 26 feet across 160 acres, as would reflect an area under 1% slope.
- Historical vegetation,
- Soils, and
- Intercepted Common Resource Area.

These primary criteria represent the land that has a potential transferability area (PTA) in Minnesota. This map is to provide intent of transferability statewide, and does not reflect discrete field scale accuracy.

Figure 124. Transferability of managed drainage in Minnesota.

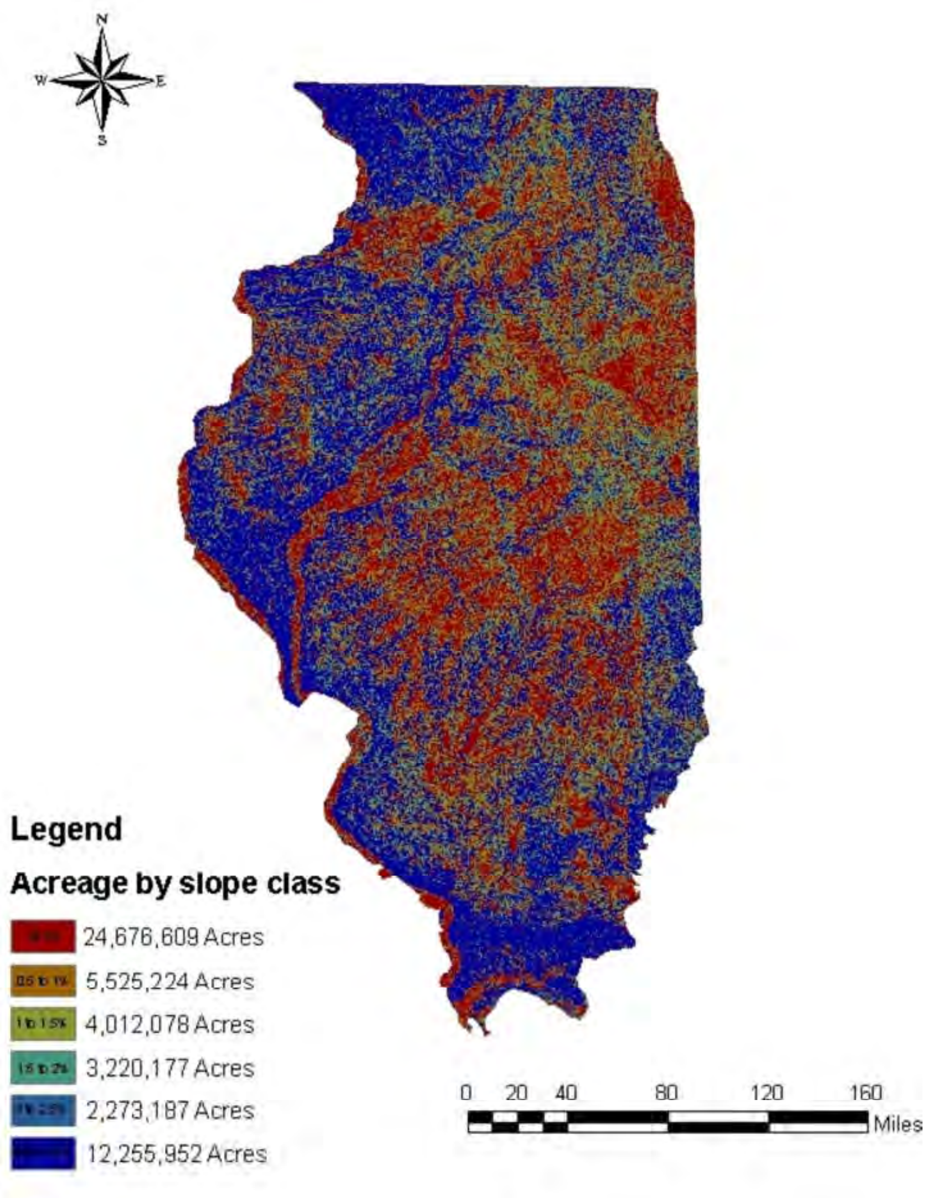


Illinois

Table 46. Quantity of Illinois drained acres by percentage of grade.

Total Acres in IL= 51,964,227	**0- 0.5% grade**	**0.5- 1.0% grade**	**1.0- 1.5% grade**	**1.5- 2.0% grade**	**2.0- 2.5% grade**
Number of acres	**24,677,609**	**5,525,224**	**4,012,078**	**3,220,177**	**2,273,187**

Figure 125. Transferability of managed drainage in Illinois.



CONCLUSIONS & RECOMMENDATIONS

Indiana

Effect on Flow: The most reliable estimate of the flow reduction due to managing drainage is from the paired statistical analysis, provided in Table 16. The annual drainage quantities in Tables 12 to 15 cannot be assumed to show the effect of drainage water management, for the reasons discussed above. Based on the paired statistical analysis, the effect of drainage water management on flow ranged from **11.5% to 17.5%,** for sites 2, 3 and 4. Although such reductions in drain flow can mean substantial progress towards reducing nitrate loss from Midwest tile drained land, they are lower than others published previously in the literature. One reason for this may be the variation in the height of the water table across the field. At Site 4 (Crawfordsville), for example, the boards were set at 6 inches (winter) and 24 inches (growing season) below the lowest point in the field, but this elevation was a relatively small area, and was approximately 5 feet lower than the high point of the field.

Effect on Nitrate Loss: The annual nitrate loss values reported in Tables 12 to 15 are of limited reliability, both because of the same factors affecting the flow estimates and also that nitrate loads are based on a relatively simple averaging method of measured nitrate concentrations. Future analyses will improve the nitrate loading estimates and also determine the overall effect of drainage water management on nitrate loss using the paired statistical analysis method.

Effect on Yield: Crop yield effects of managed drainage varied greatly from year to year, and across sites or different locations within the fields. To add to the limited yield data from this project, we also included yields from the Davis-Purdue Agricultural Center (DPAC) study, which has two replications of managed vs. conventional drainage in quadrants of a 40-acre field. Because of the influence of outlet height and timing of management on yield effects, the drainage management protocol should be specified when reporting yield effects in drainage water management studies.

Overall, yield effects were more often positive or neutral but were occasionally negative. Average annual yields differences ranged from -11% to +13% in the managed drainage fields compared to the conventional drainage fields. As with flow and other data, caution should be used with direct comparisons of yields from the two fields at any site, because inherent yield differences may be present. To account for this, a marginal effects analysis is underway by the agricultural economists on our project, and this will provide better insight into the probability of effects.

***Comments on potential for adoption**:* The cooperating farmers had generally positive views of the managed drainage. At Site 4, the cooperator did all the management of the control structure himself, helped by the fact that the contractor who installed the system left the exact number of boards to raise the water table within 6 inches of the lowest point of the field in winter. Overall, more studies are needed to clarify the effect of the height of the outlet in various situations and provide this guidance to farmers interested in adoption. Setting outlet height presents a particular dilemma in fields that have considerable topographic variation, and site-specific modeling studies may be needed to identify the best management protocol for any particular field.

Further study needed: The results provide a strong first step in understanding the effect of drainage water management at various sites in the highly-drained areas of central and northern Indiana. Challenges in accurately measuring drain flow in very flat areas where ditch water level rises above drain outlets hindered the assessment of flow and nitrate impacts, and the complex nature of analyzing yield monitor data to interpret yield effects mean that the full impact is not yet fully understood. Future assessment of drainage water management effects need to include flow and yield information both without control (prior to drainage management), and with control, which is critical to separate effects of drainage management from intrinsic field differences. As has been raised numerous times, we still need to understand where the rest of the water and nitrate go to fully assess the environmental impact of drainage water management. Further research to determine water and nitrate flow paths in various situations will strengthen our confidence in recommendations about drainage water management.

Iowa

Detailed conclusions for each site are provided below.

Hamilton County, IA: Research at this site has been conducted on a producer's field. Two field approximately 20 acres each were monitored. One field uses conventional drainage and one uses drainage water management. This site was monitored in 2007, 2008, and 2009. In 2007, conventional drainage practices were utilized on both fields and in this year the drainage from each field was similar. Drainage water management practices were implemented in the southeast field starting in 2008. During the period in which drainage water management was implemented the yields were similar for both the conventional and drainage water management areas. During the wet year of 2008, the measured subsurface drainage volumes were similar for the conventional and drainage water management fields. During 2009, the absolute value for drainage was greater from the managed drainage field. However, similar results were observed in certain months in 2008 where during periods when both systems were managed in conventional drainage mode there was great drainage from the managed drainage field. As a result to appropriately interpret these flow results a statistical paired analysis approach is needed to fully analyze and interpret this data. Monthly arithmetic average nitrate concentrations are shown for this site at this point but preliminary information indicates similar nitrate concentrations in the managed drainage and conventional drainage areas.

Story City, IA, Site Description: The research was conducted on a 22 ha (54 ac) privately owned field in central Iowa, USA (42.20° N, 93.60° W) chosen for its uniformity of soils and terrain (Brevik et al., 2000) and the presence of an existing pattern-tiled drainage system. Soils within the field are in the Kossuth (fine-loamy, mixed, superactive, mesic Typic Endoaquolls) – Ottosen (fine-loamy, mixed, superactive, mesic Aquic Hapludolls) association. Harps (fine loamy, mixed, superactive, mesic Typic Calciaquolls) and a small area of Okoboji (fine, smectitic, mesic Cumulic Vertic Endoaquolls) soils are also included. These clay loam soils were formed on nearly level, alluvial or lacustrine sediments, range from very poorly to somewhat poorly drained, and have surface soil organic carbon contents of 29 g kg-1. Large-scale row crop agriculture on these soils was possible only after installation of subsurface drainage systems (Hewes and Frandson, 1952).

In 1992, new subsurface drainage lines were installed in the field at a depth of 1.22 m. Twelve lengths of 10.2-cm diameter plastic corrugated drainpipe were installed along an east – west axis across the field. Drains were approximately 500 m in length and were installed parallel to each other with a separation of 36.5 m for the southern four tiles and 27.4 m for the other eight. Average slope along the tile drains was about 0.8%.

The 12 tiles served as the center-lines for treatment plots that we grouped into three blocks. The southern block of four tiles was retrofitted with control boxes (Agri-Drain, Corp) in the fall of 2005 to control the drainage water outlet elevation. Drainage water management at this location consisted of raising the outlet in the control structure to .305 m (1 ft) below the soil surface at the box after harvest, lowering the water table to the elevation of the tile several weeks before planting, raising the outlet to 0.61m (2 ft) below the soils surface in June after all crop management activities had been completed. In the fall the outlet elevation was lowered to the elevation of the tile two weeks before harvest before being raised again after harvest and fall tillage. Given the average slope of the field (0.8%), we assumed that raising the outlets by 1m would affect the water table out to about a maximum distance of 125 m.

The 12 tile lines were intercepted before they intersected the collection lateral on the east side of the field. A 0.6-m diameter corrugated plastic culvert was installed vertically at the interception point of each tile as a sump. Drainage was pumped from each sump into the collection lateral using a submersible sewage ejector pump equipped with a high/low level shutoff-switch. Flow volume vs. time was measured with an FP-5300 paddle wheel flow meter (Omega, Stamford, CT1) and recorded with a CR10X datalogger (Campbell Scientific, Logan, UT). Cumulative drainage was calculated by summing the yearly discharge volume from each tile and dividing by the area of each plot. The plot drainage areas were assumed equal to the length of the tile lines multiplied by the distance separating midpoints between the parallel tiles. Rainfall was measured starting in 1996 with a tipping bucket rain gage and recorded every hour at a location less than 0.5 km from the field. Missing data and precipitation data when temperatures were below 0 ºC were obtained from the National Climatic Data Center for a weighing rain gage located 2 km away.

Flow-weighted composite water samples were collected in glass jars connected by a capillary tube to the sump pump, such that a proportional sample was collected each time water was pumped. Water samples were returned to the laboratory on a weekly or shorter basis, depending on tile flow rate, and chilled to 4 ºC until analysis. Water samples were analyzed for NO_3 using a Lachat 8000 (Zellweger Analytics, Lachat Instrument Division, Milwaukee, WI). Nitrate was quantitatively reduced to nitrite and the nitrite concentration determined colorimetrically (Keeney and Nelson, 1982). The method quantitation limit was 0.5 mg-N L^{-1} as NO_3. Annual mass loss of NO_3 from each tile was calculated by multiplying the NO_3 concentration for the composite sample times the volume of water discharged during the time the composite sample was collected and summing over all samples in a calendar year. Annual flow-weighted NO_3 concentrations were computed by dividing the annual mass loss by the total annual discharge.

The field was planted to corn in 2006, and 2008 and soybean in 2007 and 2009, and was in a two-year corn – soybean rotation prior to this time. Primary tillage consisted of fall chisel plowing after soybean only. A field cultivator was used to prepare the soil for planting corn and incorporating herbicide in the spring and a row crop cultivator was used several times during the early growing season for weed control in corn. Corn was planted on a 76-cm row spacing on 13 April 2006 and 3 May 2008 at a rate of 75,000 seeds ha^{-1}. Roundup resistant soybean was drilled into corn residue on 9 May 2007 and 20 May 2009 for an approximate plant count of 370,000 plants ha^{-1}. The cooperating farmer performed all operations other than nitrogen fertilization and harvesting as part of his normal production practices.

Table 47. Planting, harvest, and outlet control dates.

Year	Crop	Planting	Harvest	Outlet lowered to 1.2 m	Outlet raised to 0.6 m	Outlet lowered to 1.2 m	Outlet raised to 0.3 m
2006	corn	13 Apr	10 Oct	-[1]	22 May	25 Sep	10 Oct
2007	soybean	9 May	3 Oct	6 Apr	25 May	-[2]	8 Nov
2008	corn	3 May	9 Oct	11 Apr	25 Jun	17 Oct	24 Nov
2009	soybean	20 May		15 Apr	16 Jun		

1. Outlet was not raised in winter of 2005-2006.
2. Outlet was not lowered because water table was below tile depth.

No N fertilizer was applied to soybean in 2007 or 2009. For corn in 2006, fertilizer rates were either 202 or 134 kg N ha^{-1}. All plots received their initial N application as 28% UAN applied in a slot by a Blue-Jet coulter applicator between the V1 and V3 crop growth stages. Several plots received half of the 134 kg N ha^{-1} at the V1 stage and half at either the V6 or V10 crop growth stage. The second applications for the V6 and V10 treatments were applied by dribbling liquid UAN (28%) in a narrow band between the rows using a high clearance sprayer with drop hoses. Differences in the N treatments are not reported in this summary. For corn in 2008 all plots received 157 kg N ha^{-1} with again some plots receiving half of the N V1 and half at the V6 or V10 growth stage.

Grain yield was measured along a single transect within each of the 12 subsurface drainage plots using either a modified Gleaner K combine or a modified John Deere 4420 combine (Colvin, 1990) with a weigh-tank in the grain hopper. The crop was harvested along a single transect within each plot. The transects were offset from the drain line by about 3 m to avoid soil disturbed by the tile installation. Along a transect, a 15.5-m (50 ft) length was harvested, the combine's forward motion stopped with the separator engaged to allow grain to finish cycling through the combine, and the grain weighed and moisture content measured. A strip, 2.29-m wide (7.5 ft or 3 rows) for corn and 3.96-m (13 ft) wide for soybean, was harvested on each transect. For corn, end rows were harvested in the transverse direction for the entire width of the plot in 2.29 m wide swaths (3 rows). Yields for the first 100 m (300 ft) were collected as this is the distance assumed to be affected by the water table management on this gently sloping field. All grain weights were adjusted to a moisture content of 155 g kg^{-1} for corn and 130 g kg^{-1}

for soybean. Grain samples were collected from each plot and grain protein determined using near-infrared spectroscopy at the Iowa State University Grain Quality Laboratory.

Rainfall and temperature were measured at al location about 1 km from the field. Potential transpiration was taken from a site 10 km south of the field (http://mesonet.agron.iastate.edu/agclimate/index.phtml). Actual evapotranspiration was computed using the appropriate crop coefficient for cumulative growing degree days since planting taken from the High Plains Regional Climate Center (http://www.hprcc.unl.edu/awdn/et/).

Yield and yearly nitrate mass loss data were analyzed for drainage and N treatment effects each year using the PROC MIXED model analysis of variance (ANOVA) procedure (SAS Institute, 1990). Yield data for all four years were normalized by the yearly mean and variance and differences for drainage and N treatments computed using the repeated measures option and an autoregressive variance covariance structure. A pre- and post-treatment paired treatment design was used to test for differences in flow caused by DWM. DWM plots were paired with conventional plots that historically received the same N treatment. The pre-treatment relationship between the paired plots was fit to a linear equation y = B0 + B1x where x is the annual flow for the conventional plot and y is the flow for the DWM plot and B0 and B1 are regression coefficients. The relationship between flow in the conventional vs. DWM plots post treatment were fitted to the equation y = B0 + B2 + (B1 + B3)x where the B0 and B1 terms are found from the pre-treatment regression and B2 and B3 regression coefficients found from fitting the post-treatment data. Significant values for either B2 or B3 indicate a significant effect on drainage for the DWM treatment.

Findings – Weather: Monthly precipitation averaged over the past 40 years is shown in Table 22b along with the monthly total precipitation for 2006–2009 and the deviation of these monthly totals from the 40-year average. For 2006-2008 the yearly precipitation exceeded the 40 yr by 1.68 to 9.72 inches, the wettest year being 2008 and the driest 2006. In 2006, precipitation was markedly less than average in May and June. June precipitation in 2007 was also much less than average. In contrast, precipitation in 2008 exceeded the monthly averages in April through July – the primary growing season for corn.

Table 48 (below) shows the difference between computed evapotranspiration during the growing season for 2006-2009. In all years there was an excess of precipitation over evapotranspiration in the months of April and May. In 2006 and 2007 the excess turned into a marked deficit in precipitation was measured for June and July. The deficit in these two months exceeded 6 inches – more water than can be stored and is available to a crop in the soil root zone of this soil. Thus, holding back some water that would normally drain in April and May would potentially increase water available to the crops in 2006 and 2007 and potentially increase yields. In contrast, rainfall in 2008 exceeded computed evapotranspiration in all months except August and September and the deficits in these two months was less than what could be stored in the soil and supplied to the crop. Thus, holding back some drainage earlier in the growing season in 2008 would not be expected to provide for a yield increase.

Table 48. Evapotranspiration - rain for April – September 2006, 2007, 2008, and 2009.

Month	2006	2007	2008	2009
	---------------------- inches	--------------------		
April	-2.92	-5.37	-4.38	-4.47
May	-0.36	-4.50	-7.83	-4.56
June	5.98	2.87	-2.01	-1.59
July	2.69	3.67	-1.41	2.86
August	-1.39	-3.78	2.87	1.60
September	-7.08	-1.23	0.25	4.18

Findings – Drainage and Nitrate Loss: Annual tile flow from the plots was quite variable reflecting the variability in seasonal rainfall. Annual tile flow ranged from 205 mm in 2006 to nearly 400 mm in 2007. The years 1996–2003 were used as pre-treatment years for plots 1–3 and the corresponding conventionally drained plots. The years 2001–2003 were used as pre-treatment years for plot 10 and the corresponding conventionally drained plots. DWM was initiated in 2006 and the years 2006–2009 were used as the post-treatment phase. Flow for 2009 included only flow through 7 September. Table 49 shows the results of the before/after regression analysis. Both B0 and B1 were significant for Plot 1 giving a slope near 1 and a significant intercept. For the post treatment period in Plot 1, only B3 is significant and is negative indicating that DWM decreased annual tile flow. For Plots 2 and 4, the intercept B0 was not significantly different than 0, so it was set to 0. For Plot 2, the B2 and B3 terms are significant with the total post-treatment slope less than the pre-treatment slope again indicating a decrease in flow with DWM. Neither B2 nor B3 were significant for Plot 10 indicating no effect of DWM in this plot. Plot 3 gives a significant and negative response for the B3 term again indicating a decrease in tile flow for DWM. Combining the four plots gives a pre-treatment intercept of 0 and a slope near 1. Both the B2 and B3 terms were significant for the combined plots indicating a significant treatment effect. For the average annual flow rate of 237 mm for the CNV, we compute a reduction in tile flow of 15.8 mm (0.62 in) for DWM using the results of the All Plots regression.

Table 49. Regression coefficients and their significance for paired conventional and drainage water management annual tile flow.

Coefficient	Plot 1		Plot 2		Plot 3		Plot 10		All Plots	
	coeff	Prob > F	coeff	Prob > F	coeff	Prob > F	coeff	Prob > F	coeff	Prob > F
B0 (mm)	28.248	0.095	0.000	N.A.†	-34.728	0.048	0.000	N.A.	0	N.A.
B1 (-)	1.003	0.000	0.929	0.000	0.993	0.000	0.890	0.003	0.946	1.7E-28
B2 (mm)	28.201	0.326	69.185	0.038	45.921	0.125	80.680	0.340	59.090	0.0219
B3 (-)	-0.349	0.019	-0.276	0.018	-0.340	0.007	-0.260	0.392	-0.315	0.0008
Prob > F	< 0.001		< 0.001		< 0.001		0.0028		< 0.001	

†Not applicable as intercept was set to 0.

Flow-weighted annual nitrate concentrations (FWANC) for the conventional drainage and DWM are shown in table 50. Averaged over the four years, nitrate concentrations for the CNV treatment were 0.5 mg N L^{-1} greater than the DWM treatment but this difference was not significant. Repeated measures analysis of the four years shows that there was a significant interaction between N treatment and drainage. For individual years, drainage type was significant in 2007 and the drainage by N treatment interaction was significant in 2006. There was no significant response to drainage in 2008 and 2009.

Table 50. Annual and 4-yr average flow weighted average nitrate concentration (FWANC) by drainage treatment and F statistic for individual year and 4-yr average comparisons.

Year		*2006*	*2007*	*2008*	*2009*	*4-yr ave.*
Crop		*corn*	*soybean*	*corn*	*Soybean*	*all*
FWANC			------------	*mg N L^{-1}*	------------	
	CD	*12.9*	*11.3*	*11.5*	*7.0*	*10.8*
	DWM	*12.7*	*10.1*	*11.3*	*6.7*	*10.3*
Prob > F						
	drain	*0.402*	*0.025*	*0.733*	*0.389*	*0.503*
	drain X N†	*0.001*	*0.002*	*0.193*	*0.209*	*< 0.001*

† N represents N rate and timing.

Mass losses of nitrate for DWM were numerically lower than for CD in every year and for the four years grouped together (Table 51). However, the differences were not statistically significant at the P = 0.05 level in any year. Grouping all four years together, the repeated measures analysis showed that mass loss of nitrate for DWM was significantly less than CNV with a significant ($P < 0.10$) interaction between drainage type and N treatment.

Table 51. Annual and 4-yr average mass loss by drainage treatment and F statistic for individual year and 4-yr average comparisons.

Year		2006	2007	2008	2009	4-yr ave.
Crop		corn	soybean	corn	soybean	all
Mass Loss		------------------------ kg ha^{-1} ----------------------------				
	CD	27.6	52.3	45.6	16.0	34.3
	DWM	20.5	30.5	35.1	13.2	23.9
Prob > F						
	drain	0.352	0.210	0.178	0.280	0.024
	Drain X N†	0.772	0.524	0.553	0.233	0.080

†N represents N rate and timing.

Findings – Yields: Average yields by drainage for 2006-2009 are given in Table 52. Yields in 2007 and 2009 for soybean and 2008 for corn were high for this field due to favorable weather conditions throughout the year. Average yields for the DWM treatment were higher in 2006, 2007, and 2009 than for the conventional drainage (CNV). However, only in the soybean years 2007 and 2009 were the yield differences by drainage significant. In 2008, DWM actually resulted in about a half a bushel lower yield on average than CNV drainage. This may have been due to the relatively wet weather throughout the growing season in 2008 negating any advantage DWM would have for storing water to use when ET exceeded rainfall and soil storage. Testing for significant differences across all years using the normalized yield for each year and the repeated measures option in PROC MIXED resulted in a significant difference in yields by drainage. There was no significant interaction between drainage and N treatment for yield.

Table 52. Yearly crop yield mean (std) for conventional, CD and drainage water management, DWM for 2006 – 2009 and the 4-yr average of normalized yearly yield and the F statistic for the within year comparisons.

Year		2006	2007	2008	2009	4-yr ave
Crop		corn	soybean	corn	soybean	all
Yield/Rel. Yield		------------------- bu ac^{-1} --------------------				–
	CD	165	55.6	211.3	56.3	-0.139
		(8.2)	(2.8)	(10.4)	(2.4)	0.873
	DWM	174.2	62.2	210.9	60.0	0.507
		(8.6)	(1.9)	(4.8)	(2.6)	0.867
Prob > F						
	Drain	0.224	0.037	0.540	0.028	0.020
	Drain X N†	0.836	0.820	0.493	0.376	0.885

† N represents N rate and timing.

Conclusions: During four years of monitoring DWM at the Story City field, there was a significant 7% decrease in tile flow, no significant decrease in nitrate concentration, and a significant 30% reduction in nitrate leaching for DWM compared to conventional drainage. For the same field no yield benefits were measured for two years of corn, but a significant increase of 9% was observed averaged for two years of soybean yield. From this data, it is unclear if this yield increase in soybean vs. no increase in corn was due to weather patterns in the four years monitored or because corn and soybean respond differently to the raised water table.

Crawfordsville, IA, Site Description: Research is being conducted on modified drainage management systems on the Southeast Research Farm (SERF) in Crawfordsville, IA USA (41.19 N, 91.48 W). The site consists of Taintor (silty clay loam, fine, smectitic, mesic Vertic Argiaquolls) and Kalona (silty clay loam, fine, smectitic, mesic Vertic Endoaquolls) soils. The research site has 8 plots with two replications for each treatment. Individual plots range in size from approximately 1.2 to 2.4 ha (3-6 ac) in size for a total project area of 17 ha (42 ac). Plots are split down the middle and cropped East to West in both corn and soybeans each year and a ¾ acre wetland planted with cattail and wild rice in April of 2007. The eight plots encompass two undrained plots and six plots consisting of three drainage treatments which are as follows:

- Two plots conventional drainage (4 ft tile depth with 60 ft spacing),
- Two plots shallow drainage (2.5 ft tile depth with 40 ft spacing),
- Two plots controlled (4 ft tile depth with 60 ft spacing with controls during the winter and summer and free flow during planting and harvesting).

Tiles lines are laid out in a north-south orientation with interior tiles being continuously monitored for flow rate with a V-notch weir and pressure transducer and water samples were taken by grab sampling outflow on a weekly basis for assessment of nitrate-nitrogen levels. Border tiles on each plot are to prevent flow from adjacent plots and these tiles are not monitored. The control gates for the controlled drainage plots are opened late April to early May prior to planting and closed after planting is completed generally in the 1st two weeks of June. Control gates are then reopened in early to mid-September prior to harvest and closed again after fall tillage is completed generally in early November.

Statistical analyses were conducted using Statistical Analysis System software (SAS, 2003). The general linear model (GLM) procedure was used to determine the statistical significance of treatment effects on subsurface drainage and crop yield. The mean values for the subsurface drainage and corn yield were separated using a least significance test at $p = 0.05$ (LSD 0.05).

Findings – Weather: Precipitation at the site is collected by three different means: mesonet, electronic data logger, and catch gauge. The mesonet and data logger collect data continuously and the catch gauge data is collected daily from the month of March through October. Precipitation data shows that there was less rainfall during the growing season in 2008 than in 2007.

Findings – Drainage and Nitrate Concentration: Monthly and annual drainage in the conventional tile plots is noticeably higher than drainage from the shallow and managed tile systems; however, major variation in a given year between plots shows little significant difference in any of the treatments with the exception of shallow drainage in 2008. Averaging treatments over the three-year study period, accounting for annual variation, shows an increase in drainage volume from the conventionally drained plots (Table 52). Groundwater monitoring shows shallow and controlled drainage plots track similarly throughout the year with nearly an 8- inch difference in average groundwater depth between conventional drainage and both the managed and shallow plots (Table 54).

Table 53. Annual drainage from the three treatment types. North and South plots averaged. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

	Drainage (in)			
Treatment	2007	2008	2009	3-Year Average
Conventional	10.1a	12.1a	23.1a	15.1a
Managed	7.1a	9.2ab	13.9ab	10.1b
Shallow	7.2a	5.6b	13.2b	8.7b

Table 54. Monthly groundwater depth for all treatments. UD is undrained, CDis conventional drainage, MD is managed drainage, and SD is shallow drainage. Unavailable data is indicated with NA.

	2007 (ft)				2008 (ft)				2009 (ft)			
Month	UD	CD	MD	SD	UD	CD	MD	SD	UD	CD	MD	SD
January	NA	NA	NA	NA	3.39	5.16	3.98	4.49	4.45	5.51	5.20	5.04
February	NA	NA	NA	NA	4.72	5.71	5.55	5.16	4.41	5.63	5.28	5.00
March	NA	NA	NA	NA	3.78	5.43	4.65	4.84	2.87	5.00	3.70	4.37
April	NA	NA	NA	NA	2.80	5.00	3.94	4.33	3.70	5.00	4.49	4.53
May	NA	NA	NA	NA	3.54	5.08	4.57	4.41	2.68	4.88	4.49	4.06
June	NA	NA	NA	NA	2.76	4.88	3.94	4.06	0.63	4.53	3.46	3.23
July	0.51	6.89	6.30	6.42	NA	NA	NA	NA	1.46	4.92	4.33	4.06
August	4.53	6.85	5.87	4.33	4.84	6.81	6.30	6.26	2.17	5.16	5.00	4.96
September	4.13	5.59	4.92	5.31	3.70	5.63	4.76	5.00	2.13	5.39	5.28	5.20
October	3.35	4.96	4.02	4.57	4.17	5.47	4.96	4.96	1.69	4.65	4.21	3.98
November	4.49	5.351	5.24	5.08	4.13	5.31	4.80	4.72	0.00	5.04	3.66	4.02
December	4.09	5.35	4.84	4.72	4.09	5.35	4.92	4.65	NA	NA	NA	NA
Average	3.52	5.86	5.20	5.07	3.81	5.44	4.76	4.81	2.38	5.06	4.46	4.40

Nitrate concentrations are highest in the shallow drainage plots and concentrations for controlled and conventional plots have similar averages with more variability (between plots) in the controlled system (Fig. 125 and 126). However, mass losses of nitrate are higher in the conventional plots than the controlled and shallow plots due to higher drainage flow in the conventional plots. The estimated nitrate loss during 2007-2008 was 21.7, 10.5 and 14.1 lbs/acre for conventional, controlled, and shallow plots, respectively.

Figure 126. 2008 grab sample Nitrate concentrations.

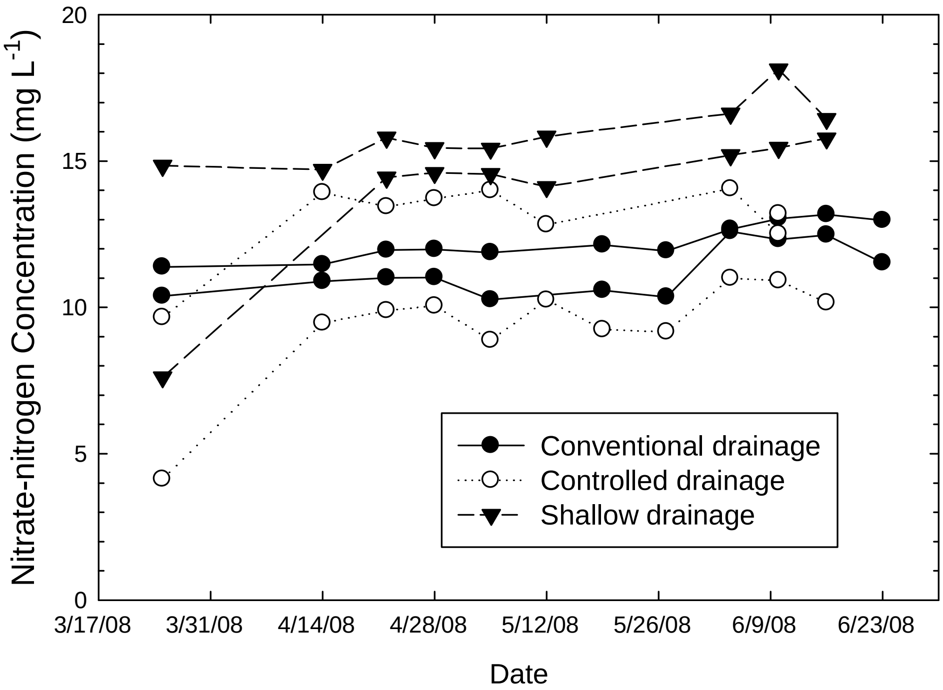
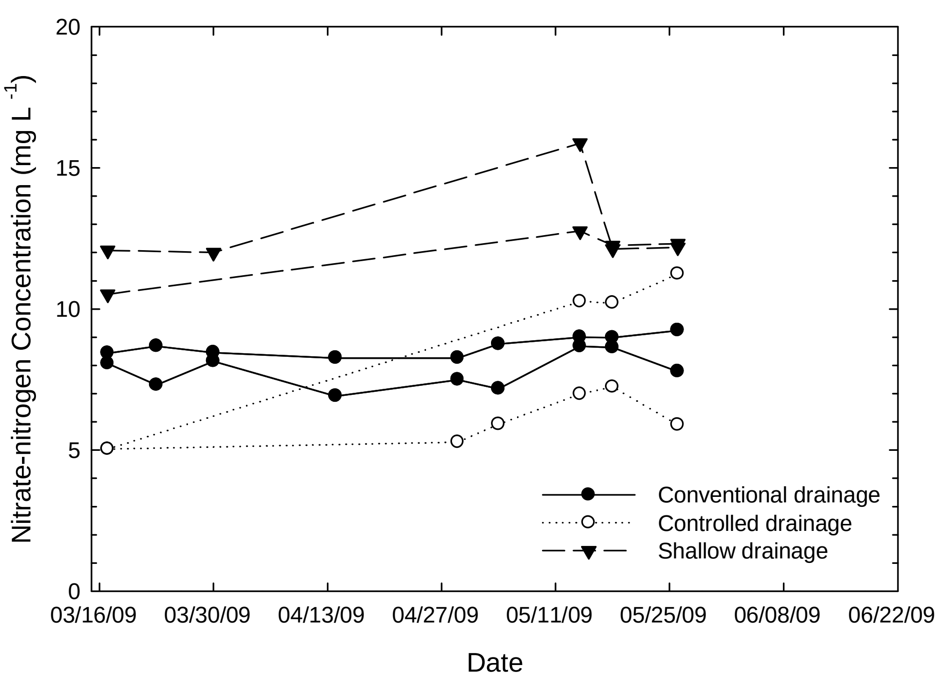


Figure 127. 2009 grab sample Nitrate concentrations.



Findings – Yields: Yields of similar treatments were averaged for a total yield per treatment value (Fig. 127 and 128). Average yields varied widely over the years and treatments. However, 2008 showed less variability in yields than 2007 or 2009. In 2007, all treatments except for the no drainage treatment with corn were greater than in 2008 for both corn and soybeans. In 2007, corn and soybean yields were the lowest in the no drainage treatment and highest in the conventional drainage treatment. In contrast, 2008 yields for the no drainage treatment were the highest among all the treatments which is probably due to the rainfall experienced in 2008 that was very close to the 10-year average. Corn yields in 2009 were lower than in 2007 or 2008, which is likely due to high rainfall during 2009. Soybean yields in 2009 were higher in the drained plots than in the undrained plots, likely due to less water stress during growth period of the soybeans. As noted from the groundwater depth information the greatest difference in average water table depth between the undrained and drained treatments was observed in 2009.

Figure 128. 2007-2009 corn yields with standard deviations. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

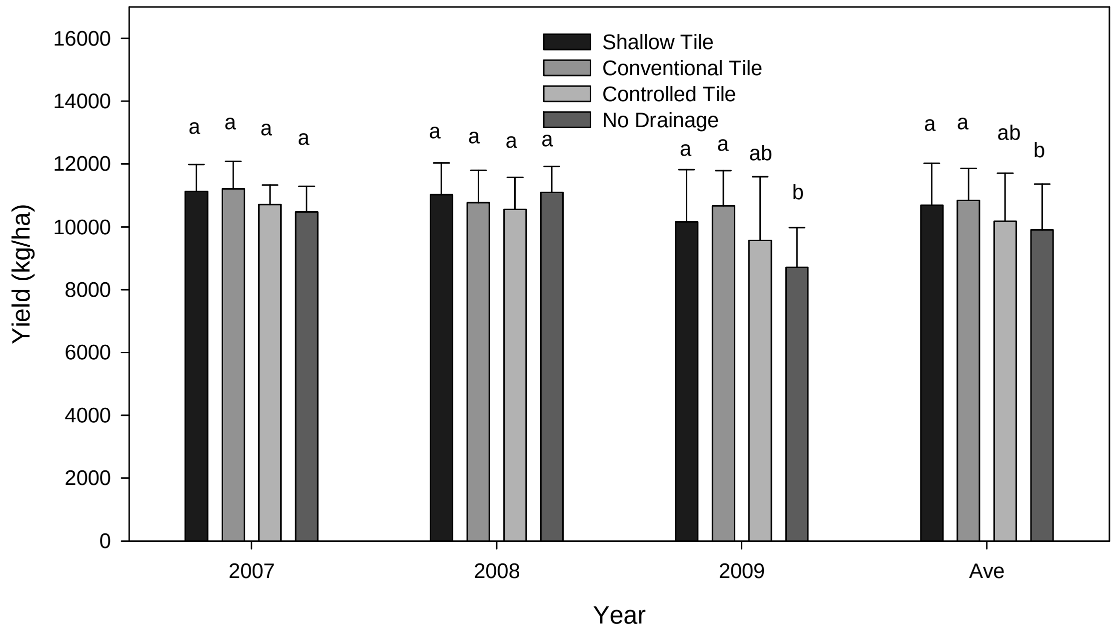
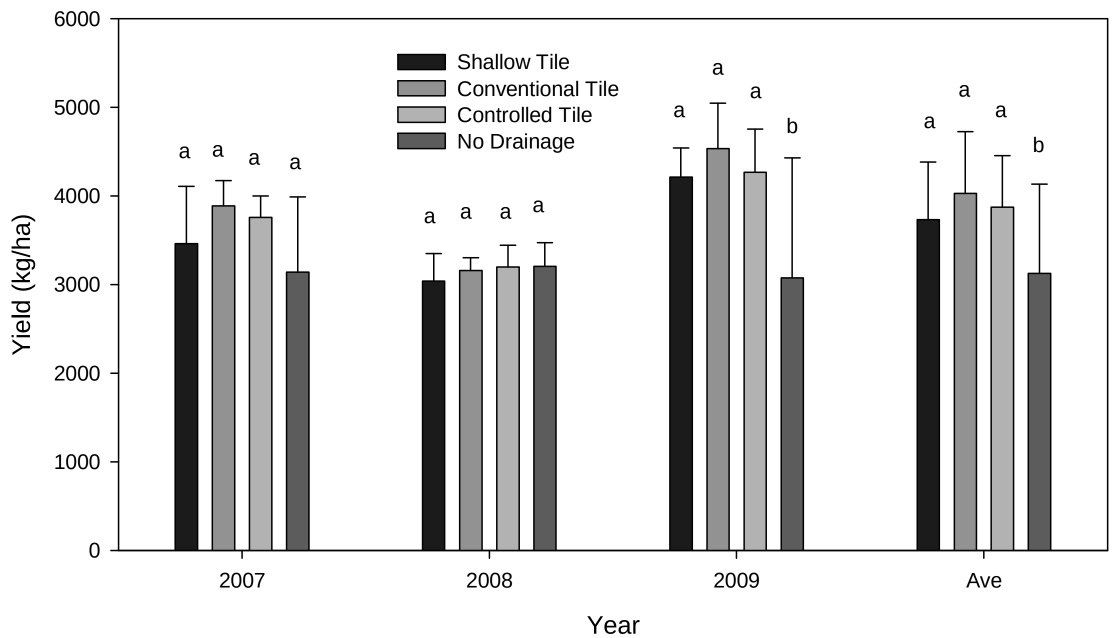


Figure 129. 2007-2009 soybean yields with standard deviations. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).



Conclusion: From the three-year monitoring period drainage water management through controlled or shallow drainage significantly reduced overall drainage by 30 to 40%. For the controlled drainage compared to the conventional drainage treatments the primary periods for reduction in drainage volumes were from June through August whereas volume reductions were observed during most months when comparing the conventional and shallow drainage treatments. The undrained plots consistently had shallower water tables. This was especially the case in the wet year of 2009 and in this year the undrained plots had significantly lower crop yield than the drained plots. Over the three-year study period the drainage water management treatments did not have significantly different crop yields than the conventional drainage treatment.

Pekin, IA, Site Description: Drainage management practices are being evaluated at the Pekin school drainage facility in Pekin, Iowa, USA (41.16° N, 92.16° W). All soils at the site are a Taintor – silty clay loam with mild slopes (<1%) except for a pothole in the northwest corner. There are a total of nine plots at this facility each being three acres. The plots are split down the middle to accommodate both corn and soybeans, which allows for assessment of the rotation as a whole. Three different management practices are being utilized and evaluated. The treatments include the following:

- Three plots with conventional drainage (drain tile at 3.5-4 ft deep),
- Three plots with managed conventional drainage with free flow in the spring (April –May) and fall (September-October). The outlet control was set at 2 ft below the ground surface except during free flow, and
- Three plots with pseudo-shallow drainage (control structure set at 2 ft below surface). This treatment would be used to represent a system similar to shallow drainage.

These three treatments are being evaluated to investigate the impacts of drainage management practices on drainage volume, nutrient concentrations in the subsurface drainage, and grain yield. Since significant climate variability exists and the response of variable weather conditions on drainage management systems is needed it is important to evaluate the treatment response over the entire duration of the project.

Limited data collection at this site was started in 2004. Each plot has a conventional corn-soybean rotation with decisions on which hybrids to use each season being made at the first of the year.

Findings – Weather: On average, 33.15 inches of precipitation is recorded for the region (1971 to 2000). Crop years 2005 and 2006 were both unusually dry years at this site. In 2005, 24.93 inches were recorded with precipitation from mid-March through the end of the year less than 18 inches and only about 8 inches from mid-March through the end of June. In 2006, slightly less total precipitation was recorded with 22.83 inches, which is less than 2/3 of normal amount. Precipitation recorded in 2007 was 10 inches above normal totaling 43.32 inches. Precipitation in 2008 tracked along with the historic average quite well with the final amount of rain approximately 1 inch below normal. In most of 2009, recorded precipitation was above normal with a total of 36 inches from January through mid-November Drainage and Nitrate Concentration.

Findings – Drainage and Nitrate Concentration: During the dry 2005 and 2006, there was on average slightly less than 4 inches of drain flow from the conventional drainage plots, while the total drain flow was only 1.3 and 0.3 inches respectively for the controlled and the pseudo-shallow drainage plots. It is likely that there is some lateral seepage from the pseudo-shallow drainage and managed drainage plots to the conventional drainage plots. In 2007 with the above normal precipitation, 42% of precipitation became conventional subsurface drainage. The managed drainage system drainage volume was reduced by more than one-half to 19% of all precipitation. The shallow drainage system yielded only 12% of the annual precipitation. Respectively, annual drainage volumes were 18.7, 8.6 and 5.2 inches for each of the three systems. In 2008 with the approximately average precipitation, 48% of precipitation exited the soil through the conventional subsurface drainage network. The controlled drainage system drainage volume was reduced to 18% of precipitation. The shallow drainage system yielded substantially less with 10% of precipitation. Respectively, drainage volumes were 16.6, 6.2, and 3.3 inches for each of the three systems. In 2009, with the above normal precipitation, 67% of precipitation became conventional subsurface drainage. The controlled drainage system drainage volume was reduced to 34% of precipitation. The shallow drainage system yielded only 19% of precipitation. Respectively, drainage volumes were 24.2, 12.1, and 6.7 inches for each of the three systems. More detailed monthly drainage values along with corresponding rainfall are shown in Table 55.

Water samples to determine NO_3-N concentration were only available in April and May, in 2005-06, due to low flow conditions encountered. In 2007, water samples were available in late March, April, May, June, July, August and early September before drainage ceased. Sampling in 2008 was similar to 2007. Water samples were only available from early April to mid-June in 2009. Listed in Table 56 are flow-weighted NO_3-N concentrations for all treatments determined by summing individual loadings through the season and dividing it by the total drainage, thereby weighting the final value to reflect a specific drainage periods influence on the overall value. Values between treatments during individual years were very similar. When comparing years, values were much higher in 2007. However, mass losses of nitrate are highest in the conventional plots than the controlled and shallow plots due to higher drainage flow in the conventional plots. The estimated nitrate loss during 2007-2008 was 35.3, 13.6 and 10.5 lbs/acre for conventional, managed, and shallow plots, respectively.

Table 55. Monthly drainage and precipitation for study years 2005 through 2009 from the three treatments at the Pekin, IA drainage study site). Abbreviation: CD-conventional drainage, MD-managed drainage, SD-shallow drainage, P-precipitation.

Drainage in inches

	2005				2006			
Month	CD	MD	SD	P	CD	MD	SD	P
January	0	0	0	2.64	0	0	0	2.33
February	0	0	0	1.41	0	0	0	0.34
March	0	0	0	0.69	2.10	0.17	0.14	3.88
April	2.18	0.87	0.22	2.95	0.98	0.72	0.05	2.99
May	0.36	0.23	0.02	1.49	0.37	0.24	0.01	1.22
June	0.91	0.28	0.03	2.94	0.02	0.03	0	1.48
July	0.13	0.01	0.01	2.21	0	0	0	3.16
August	0	0	0	2.64	0	0	0	0.77
September	0	0	0	3.26	0	0	0	0.29
October	0	0	0	1.66	0	0	0	2.23
November	0	0	0	1.92	0	0	0	1.92
December	0	0	0	1.11	0	0	0	2.23
Total	**3.58**	**1.39**	**0.27**	**24.93**	**3.47**	**1.15**	**0.20**	**22.83**

Drainage in inches

	2007				2008				2009			
Month	CD	MD	SD	P	CD	MD	SD	P	CD	MD	SD	P
January	0.30	0.03	0.04	0.15				0.32				0.43
February	0	0	0.01	1.02				1.59				2.01
March	1.19	0.02	0.13	3.24	2.12	0.07	0.20	1.76	1.56	0	0	5.08
April	3.85	2.86	1.32	4.45	2.86	1.19	0.27	4.98	1.55	0	0.02	3.14
May	2.50	1.90	0.77	4.13	1.34	1.46	0.22	0.42	3.89	2.90	0.94	3.30
June	4.05	0.79	1.01	6.10	6.44	2.63	2.01	8.04	7.31	2.57	2.51	5.29
July	1.61	0.18	0.25	4.81	2.64	0.56	0.63	6.82	0.21	0	0.01	2.19
August	2.23	0.80	0.85	9.51	0.34	0	0.01	2.82	2.93	1.48	1.60	10.08
September	0.17	0.02	0	5.87	0.04	0.15	0	4.71	0.30	0	0.03	0
October	2.61	2.02	0.75	3.26	0.01	0.08	0	1.19	1.44	1.30	0.23	4.37
November	0.13	0.03	0.01	0.20	0.60	0.08	0	1.57	4.98	3.82	1.34	0.11
December	0.04	0	0.01	1.64	0.21	0.03	0	0.59	1.12	1.58	0.26	
Total	**18.69**	**8.65**	**5.16**	**44.38**	**16.60**	**6.25**	**3.34**	**34.81**	**25.29**	**13.65**	**6.95**	**36.00**

Table 56. Flow-weighted nitrate concentration for all treatments (mg/L).

	Conventional		Managed		Shallow	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
2005	6.71	1.16	6.40	2.14	4.57	2.49
2006	6.92	0.59	7.20	1.44	6.72	1.86
2007	10.69	1.98	12.08	2.75	12.88	1.63
2008	6.23	2.97	5.17	3.32	5.95	2.05
2009*	6.39	2.83	7.35	2.23	7.88	1.47

* The 2009 data is not complete and for the period of April to mid-June only.

Findings – Yields: Historically, corn yields have been relatively low, when compared to state and county averages. The 2006 growing season was plagued with planting and fertilizing issues that resulted in meaningless yield data, which is not included here. Low yields in 2005 and 2007 are not, however, due to drainage management schemes as yields are very similar between treatments. The 2008 growing year produced a very nice crop with yield increases over 2007 between 80 and 90 bushel/acre. There was no corn yield data for individual plots in 2009 but the average corn yield was estimated to be 148 bu/acre.

Soybean yields have been steady with a slight increase in 2007. In 2005, a dry year, lower yields are observed on the free drainage and the shallow drainage treatments. The 2006 soybean growing season was also plagued by planting and fertilization issues, and the data is not included here. There is a slight decrease in yields in the free drainage treatment over all years when compared to the managed drainage and shallow drainage treatments; however, the decrease is slight. Since there is not a strong trend in yields with treatment, the only factor to compare between treatments is nitrate concentrations observed in the drain water.

Conclusion: Compared to the conventional drainage, the managed and shallow drainage treatments greatly reduced drain flow at the Pekin site, 63 to 93% during dry years (2005-2006) and 55 to 74% during wet years (2007-2009). Likewise, the total N loss was reduced by 61 to 70% from managed drainage plots compared to the conventional plots. There is no strong trend in yields with treatment during the study period. While the greatest flow reduction is measured at the Pekin site this is likely a result of lateral seepage losses from the 3-acre plots.

Acknowledgments: These four project sites provide data to the CIG project managed by the Agricultural Drainage Management Coalition. However, funding from a variety of sources supports or has supported various aspects of these projects. The Pekin site is primarily supported by the Iowa Department of Agriculture and Land Stewardship. The Story City site is primarily supported by the USDA-ARS National Soil Tilth Laboratory. The Crawfordsville site was established through a grant from the Iowa-NRCS and this grant continues to provide some support for this project but the CIG provides additional support. The Hamilton county site was established primarily through support from

the Iowa-NRCS through the Prairie Rivers RC&D. The CIG is providing primary support for continued data collection at this site. Support from these organizations provides the opportunity for data collection from a variety of existing sites to further our understanding of the performance of drainage water management in Iowa.

Ohio

Data not provided.

Minnesota

Interpretation of Data: It is important to note that no statistical design or analysis has been performed on the data presented in this report. Observed differences in crop yields, and drainage or nitrate-nitrogen outflows are simply differences and do not imply cause and effect due to managed drainage.

Annual Precipitation: Drainage systems respond to the magnitude and timing of precipitation events throughout the year. It is expected that precipitation factors will play a pivotal role in the efficacy of managed drainage. Annual precipitation for the four demonstration sites was at, or more frequently, below the 30-year annual precipitation averages for these locations. Comparisons of monthly precipitation amounts with the 30-year averages were not made.

Crop Yield: Average crop yields for the drainage demonstration sites were extracted from combine yield monitor data. Yield differences at a site between different drainage management practices and whole field averages were determined using GIS techniques. Corn and soybean yields ranged from 160 to 205 and 46 to 57 bu/acre, respectively, for the four demonstration sites, illustrating that yield was variable and subject to effects of nutrient management (rate, timing, source, and method of application), background soil fertility level, pest management, soil type, seasonal precipitation, and drainage management. Differences were observed among drainage sites during both corn and soybean production years and these differences were very small (a few bushels, at best) and not consistent by drainage practice. Statistical design and a greater number of cropping seasons would be required to discern the effects of drainage management practices on crop yield.

Annual Drainage Volume: Annual drainage volumes from less than one to 8 inches were observed among the four demonstration sites. Differences in annual drainage volumes were observed in all years between managed and conventional drainage systems for the demonstration sites. These differences ranged from 10% increases to 76% decreases for managed drainage flows compared to conventional drainage. Lower flows were more often observed for managed drainage compared to conventional drainage.

Annual Nitrate Loss: Annual nitrate-nitrogen loads ranged from 0.2 to 40 lbs/acre for the four demonstration sites, illustrating that nitrate-nitrogen movement from artificially drained fields is highly variable and subject to effects of nutrient management (rate, timing, source, and method of application), soil type, seasonal precipitation, and drainage management. Reductions in nitrate losses from managed drainage have been closely associated in other studies, with reductions in annual drainage volumes. Differences in annual nitrate-nitrogen losses from 1% to 97% were observed between the managed and conventional drainage sites. The 97% occurred in 2009 when almost zero flow was observed on one of the managed drainage sites. Greater nitrate-nitrogen losses were observed in back-to-back years for managed drainage compared to conventional at one location, while lower nitrate-nitrogen losses for managed drainage were consistently observed for another location.

Further Study Needed: As stated above, this project demonstrated in part, that the efficacy of drainage management practices can be wide ranging and is likely dependent on design and site factors. This project does not provide sufficient information to determine the relative effects of these many site and management factors. Additional field research is needed where statistical design is used to control for these factors. In addition, computer modeling research must be a component of future research plans so that the efficacy of drainage water management can be evaluated over long time-frames and for many soil-location combinations. Economics research is also recommended to more completely describe the costs and benefits (including environmental benefits) of managed drainage systems.

Illinois

The results are indicative that drainage water management is efficacious in reducing nitrate loads from subsurface drainage systems without having an adverse effect on crop yield. Because of the inherent variability in yield, a longer period of observation is required to characterize yield benefits.

Agricultural Drainage Management Coalition

Conclusions and lessons learned from this Conservation Innovation Grant are very positive for environmental benefits of reducing drainage outflows and nutrient levels. However, trying to quantify yield benefits is more complex.

All of the demonstration sites show positive reductions in nitrates and outflows. Amounts vary by site due to timing of precipitation events, intensity of precipitation events, condition of the soil profile (frozen/thawed, moisture content,, type of crop and growing conditions), and the amount of organic or commercial nutrients that may have been applied. For average weather and growing conditions, producers should be able to quantify reductions in the 30% to 60% level. Demonstrating the amount of outflows and nutrient reductions was done using weirs or mag flow meters and taking grab samples of the drainage outflows. Developing a protocol for that was not difficult. Once the information was gathered, it needed to be reviewed for accuracy.

One of the issues that needed to be resolved was checking the accuracy of the equipment to gauge the flows and respond to power outages of the mag flow meters. After those issues were resolved, collecting data went reasonably well.

Trying to determine yield impacts was very difficult from the start, because the grant application did not define an adequate protocol for the collaborators and producers to follow. After reviewing the yield information from the different sites, it appears that there is no correlation to make yield determinations. A protocol should have been developed during the abstract portion of the grant request. In order to make a valid comparison between the free drainage plots and the managed plots the following criteria should have been in place:

- Soil sampling by grid,
- Checking for field compaction,
- Random stand counts by variety,
- Field monitoring for weeds or herbicide damage and insect infestations,
- Hand sampling for yield, and
- Aerial flyovers to observe any cropping differences or stress.

To do an accurate analysis for yield, a protocol should be developed and checked for accuracy. Then a two-year demonstration and collection of information on several selected sites would provide more accurate information. It may be of some benefit to fund a project to make that determination.

ADMC will include discussion of what was learned about studying/ demonstrating DWM (including the challenges and shortcomings of this study, and ideas for future, tighter protocols), and what ADMC's recommendations are to NRCS for DWM research, promotion and adoption.

CIG CHALLENGES

The size and scope of the Conservation Innovation Grant to demonstrate drainage water management for Midwest row-crop agriculture was extremely complicated to manage. Due to the challenges of collaborating with five states and 20 different locations, it was difficult to oversee each state project and react to problems that arose. When the protocol for the project was developed, a timeline of goals should have been part of the process to keep the projects on track and to solve problems as they developed.

It appears that there should be a process to define the protocols for the projects before installation. The other area of concern was trying to analysis for two different parameters at the same time. Water quality and quantity should have been demonstrated separately from the yield analysis to quantify the results.

In selecting partners to use as cooperators, it is important to define the difference between demonstrating a practice and collecting data to define and justify the cause and effect of the practice. During this CIG, it was hard for some of the researchers to separate the two.

Despite the challenges, the CIG project provided unprecedented insight into the potential of drainage water management across the Midwest.

We have begun to quantify the environmental benefits of the practice, generating important data on the reduction in nitrate-nitrogen in controlled outflows and identifying key questions that will lead to further understanding of how drainage water management can help address nutrient enrichment in surface waters throughout the Mississippi River watershed and into the Gulf of Mexico. The data will also be extremely important in developing policies and programs that incentivize drainage water management.

We have tested the design and operation of drainage water management systems across a wide variety of fields and growing conditions, gathering excellent insight from farmers, drainage contractors and agency personnel on the technology and practice. The perspective we gained will be invaluable in fine-tuning system design and training farmers, contractors and conservationists in the use of drainage water management.

The outreach component of the CIG program also allowed us to make well over one million impressions on farmers, contractors, resource agency and extension personnel and other stakeholders through meetings, articles and literature on drainage water management, creating a foundation of awareness and receptiveness for future communications and insight.

In all, this CIG funded a seminal project in the realm of drainage water management, sure to be followed by further insight and, ultimately, better management of agricultural drainage water across millions of acres of Midwestern farmland.

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