Questions and Answers about Saturated Buffers for the Midwest

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WHAT IS A SATURATED BUFFER?

A saturated buffer is an edge-of-field conservation practice that removes nitrate from subsurface tile drainage water before it enters ditches, streams, and other surface waters. When properly sited and installed, a saturated buffer will remove nitrate whenever the tile is flowing and requires little annual maintenance to ensure effective operation.

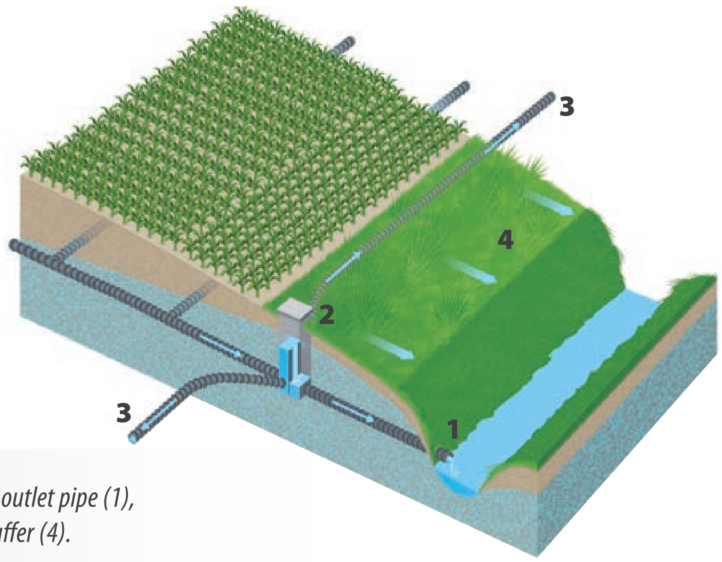

Figure 1: *A typical saturated buffer layout consisting of a non-perforated tile outlet pipe (1), water control structure (2), perforated distribution pipe (3), and vegetated buffer (4).*

The basic components of a saturated buffer are a non-perforated tile outlet pipe, a water control structure, a perforated distribution pipe, and a vegetated buffer (Figure 1). The water control structure is installed along the tile outlet pipe and within the buffer. The distribution pipes are connected to the water control structure and installed within the buffer roughly parallel to the stream at a shallow depth below the ground surface.

When the saturated buffer is operating, the water control structure directs a portion of the subsurface tile drainage water into the buffer rather than discharging directly to surface water. The water control structure raises the water level creating pressure that allows the diverted water to fill the distribution pipe and slowly push its way through the buffer's subsoil and into the stream. While moving to the stream, the nitrate contained within the water is either removed by denitrification, a soil microbial process that converts nitrate to harmless nitrogen gas, or is taken up by actively growing vegetation within the buffer and incorporated into the plant biomass.

To prevent the reduction of drainage within the cropped area, the water control structure is designed to allow any drainage water that exceeds the buffer's treatment capacity to bypass the system and exit through the regular tile outlet.

Examples of a Saturated Buffer

SATURATED BUFFER IN A STREAM MEANDER

The saturated buffer was installed in Wilkin County, Northwest Minnesota, in the late fall 2015 at the same time as the drainage system. The intercepted tile outlet was a 6-inch diameter non-perforated plastic tile. The distribution pipe was 4 inches in diameter and was installed at 0% slope at a depth of 3 feet. The perforated distribution pipe was installed along 700 feet of a meandering stream at a distance of 50 feet from the banks. Non-perforated pipe was used where the buffer was narrower than 50 feet wide. Since 2016 the buffer removed 60% to 95% of the nitrate in the drainage water without impacting the efficiency of the drainage system in the field. Multiple distribution pipes were installed and monitored, but it is unclear if this enhances the efficiency of the buffer.

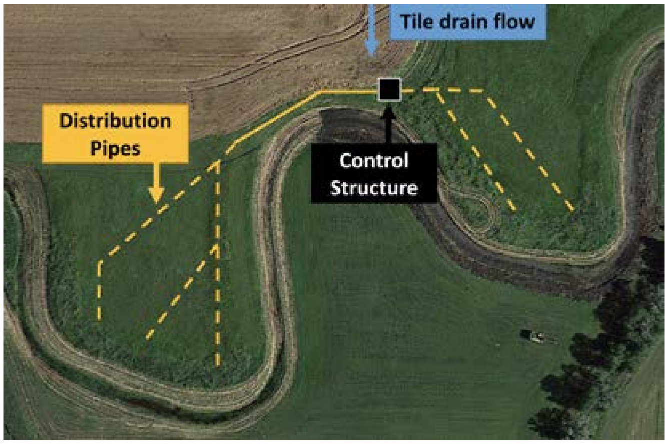

Figure A: *Saturated buffer with multiple distribution pipes to maximize coverage in the stream meanders.*

SATURATED BUFFER ALONG WOODED RIPARIAN BUFFER

The first saturated buffer installed was in Hamilton County, Iowa, on an existing buffer adjacent to Bear Creek in 2010. The intercepted tile outlet at this site was a 6-inch diameter plastic tile. The riparian buffer, established in 1995, consisted of a 20-foot wide strip of silver maple trees next to the stream, a 20-foot wide strip of mixed shrubs, then a 26-foot wide strip of switchgrass. A 4-inch distribution pipe was installed at a depth of 2.5 feet starting at the control box and extending 900 feet in the upstream direction and 150 feet in the downstream direction at 0% slope.

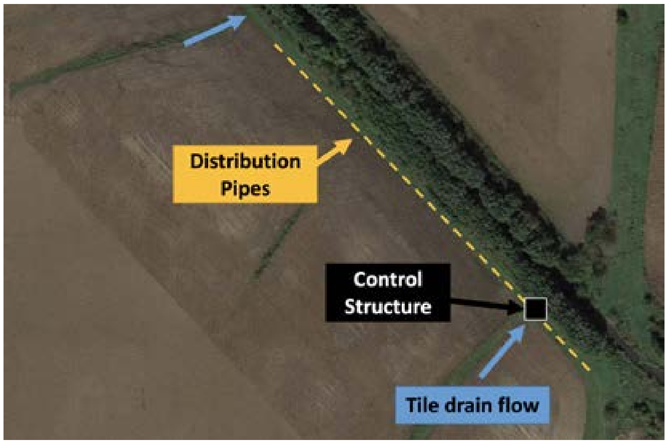

Figure B: *Overhead view of the Bear Creek saturated buffer. Distribution pipe to the east (right) was extended to the property line, to the west (left) until encountering another tile outlet.*

Figure C: *Bear Creek saturated buffer during and 2 years after installation.*

SATURATED BUFFER ALONG WOODED RIPARIAN BUFFER AND HAYED

The first demonstration site in Missouri was installed in the summer of 2017 in Knox County, Northeast Missouri. The site has a developed riparian buffer with 30 feet of trees along the drainage ditch. A 6-inch non-perforated plastic tile supplies water to the saturated buffer, and 300 feet of 4-inch perforated distribution lines were installed 90 feet from the stream bank at 0.3% (left line) and 0.5% (right line) slopes at a depth of 2.5 feet below the soil surface. The site will be able to treat subsurface drainage water as well as water captured in a 13-acre reservoir.

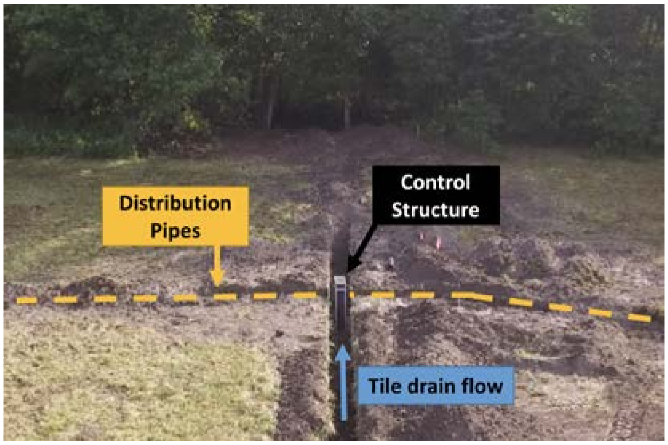

Figure D: *Saturated buffer during installation in Missouri.*

Figure E: *Haying being done within the saturated buffer for additional nutrient removal.*

SATURATED BUFFER ALONG OPEN DITCH

The saturated buffer was installed in Mercer County, Ohio, on an existing riparian buffer adjacent to Dennison Ditch in 2015. The saturated buffer is set at a 0-degree slope and intercepts an 8-inch diameter plastic tile which drains about 20 field acres. The buffer filters nutrients through a riparian area ranging from 50 to 75 feet in width and planted with a diverse prairie seed mixture. Preliminary estimates of nitrate-N removal are at or exceeding 75%. Research efforts at this site were made possible through funding from the Great Lakes Restoration Initiative supported by the Ohio Environmental Protection Agency (Award WRIGHT-FDSEDM14).

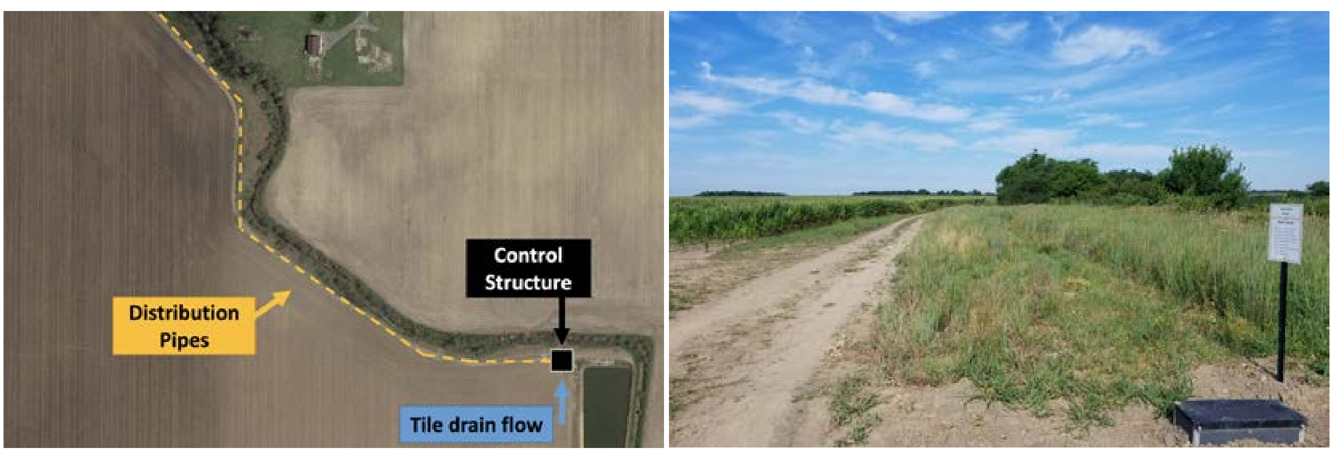

Figure F: *Saturated buffer installed in Ohio along open ditch.*

WHAT SITES ARE SUITABLE?

To be suitable for a saturated buffer, a site needs specific landscape and soil characteristics.

Existing or planned buffer and tile outlet: There needs to be a tile outlet crossing an existing or planned buffer that can be intercepted. The tile outlet must drain a suitably large area to provide sufficient flow and nitrate to treat within the saturated buffer. The buffer must be at least 30 feet wide and planted to perennial vegetation. A site with a perforated tile main running parallel to the stream may also be suitable.

Soil that supports denitrification: Soils within the buffer need to be suitable for a saturated buffer. Soils with a gravel or sand layer within the top 4 feet of the surface are not suitable because water will move quickly through these highly permeable layers. A loam or clay loam soil is ideal. If the soil has too much clay, it may not be very permeable and thus not much water will infiltrate the buffer. The soils must also show evidence of a high water table (presence of reduced or gleyed layers), either seasonally or continuously. A high water table is a good indication that the water introduced into the saturated buffer will flow laterally toward the stream or other waterbody as shallow groundwater. Finally, the soil needs to contain at least 1.2% organic matter to a depth of 2.5 feet to help support denitrification.

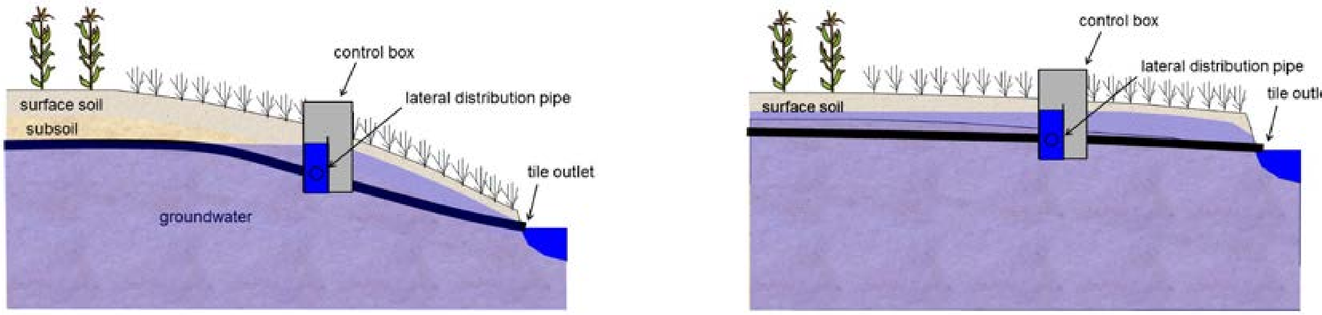

***Figure 2:** Left: Suitable locations allow the water table to be raised within the buffer without raising the water table within the cropped field. Right: Less desirable locations, where the field and buffer are nearly level, require the water table at the control box to be manually adjusted at least twice a year so as to not adversely affect the cropped field.*

Buffer that is lower in elevation than the field: The buffer should be a few feet lower in elevation than the adjacent cropped field to allow the water table to be raised near the soil surface within the saturated buffer without affecting the drainage within the field. Saturation of the buffer will not affect soil moisture in the cropped field in this instance, which allows the saturated buffer to function well throughout the year with no management required.

If the buffer is not sufficiently lower in elevation than the cropped field, a saturated buffer is still possible but less desirable. The water level within the saturated buffer will need to be adjusted seasonally by the farmer to keep water from the buffer from saturating part of the adjacent field. The water level is lowered during planting to provide adequate drainage within the field and raised the remainder of the year to direct water into the buffer.

Stable streambanks: Stream banks should be less than 8 feet in height. This ensures that water infiltrating into the buffer does not create a seepage face along the streambank or ditch bank resulting in bank instability and possible sloughing. Streams that are incised deeper than 8 feet can be used for a saturated buffer if a slope stability analysis shows an acceptable level of safety against saturated streambank failure. To date, there have been no reports of a saturated buffer causing stream bank sloughing.

***Figure 3:** Examples of a stable streambank suitable for saturated buffer placement (left), an unsuitable, unstable streambank (center), and the unsuitable presence of a coarse gravel layer near the soil surface (right).*

HOW DO SATURATED BUFFERS BENEFIT WATER QUALITY?

A saturated buffer is most effective as a nitrate removal practice. Although there is some evidence that saturated buffers may also remove soluble phosphorus, the effects have not been consistent. On an annual basis, saturated buffers remove anywhere from 7% to 92% of the nitrate load, with an average of 42% removal, within subsurface tile drainage water leaving the field tile outlet (Figure 4). The longer the saturated buffer, the more water that can infiltrate into the buffer which increases nitrate removal. The percentage of nitrate removed from tile flow will be lower if most of the tile water discharges directly to the stream through the bypass rather than being redirected into the buffer. The bypass is a function of the length of the distribution pipe and infiltration capacity of the soil within the buffer. The presence of clay-rich soils that do not facilitate water movement will reduce infiltration compared to more loamy soils.

DO SATURATED BUFFERS AFFECT CROP YIELD?

If properly located at a lower elevation than the cropped field or actively managed, saturated buffers should have no effect on yield in the adjacent cropped fields. It is important that the buffer slopes away from the field toward the stream, so as to not impact the water table within the cropped field.

A saturated buffer may impact the perennial vegetation within the buffer, as the water table in the buffer will be higher during the time of year the tiles are flowing. Since most riparian vegetation is well suited to wet soil, no negative impacts are expected, but a net increase in the growth of vegetation within the buffer is possible due to increased water and nutrient availability.

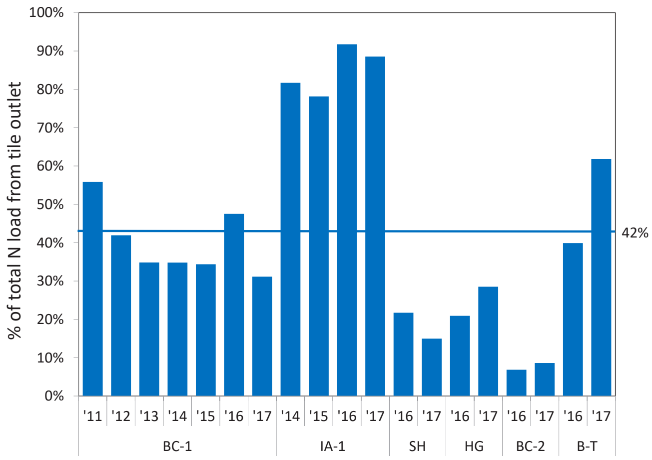

Figure 4: *Results for 6 saturated buffers monitored from 2 to 7 years. Nitrate removed in the saturated buffer varies from 7% to 92% (Jaynes and Isenhart, 2018).*

HOW LONG SHOULD SATURATED BUFFERS BE?

A saturated buffer should be as long as possible to maximize nitrate removal capacity. The length of the saturated buffer will typically be limited by the length of the buffer, property boundaries, or physical features in the landscape, such as the presence of deep gullies, roads or ditches that preclude running the distribution pipe through them. Another factor that will affect the size of the buffer will be having to install the distribution pipe too deep when extending it up grade along the stream, or conversely, having to install the distribution pipe too shallow when extending down grade along the stream. If installing under any of the USDA cost-share programs, the length of the saturated buffer may have to be sufficient to infiltrate a fixed percentage of the tile system flow. This requirement may vary by state, so consult the Saturated Buffer Conservation Practice Standard (604) document for your state.

The saturated buffer should be located on a tile outlet with sufficient flow to provide water to the saturated buffer. An outlet at least 6 inches in diameter is most likely draining a large enough area to provide sufficient flow to make installation of a saturated buffer economically feasible, considering that the higher volume of flow treated lowers the cost per pound of nitrate removed. At peak flows on larger outlets, the saturated buffer will not infiltrate all of the water, and the percentage of treated water will be reduced. However, larger outlets typically flow for a longer time providing greater opportunity for nitrate removal, resulting in more pounds of nitrate removed and not entering surface water.

Figure 5: *Installation of a saturated buffer using a wheel trencher to lay the distribution pipe.*

WHAT TYPE OF MANAGEMENT IS REQUIRED?

When properly sited and designed so that the buffer is at a lower elevation than the field, very little management is needed. The depth settings of the water control structure should not have to be adjusted once they are set unless seasonal management is needed for more level fields. An annual inspection of the control structure is needed, and any accumulated debris or sediment should be removed.

Root infestation in the distribution pipe has been reported, so it is a good idea to remove any woody vegetation within the buffer near the distribution pipe. Some deep-rooted grasses and forbs could also contribute to root infestation in the distribution pipe, but no data currently exists to evaluate which species pose a greater concern than others. Mowing and haying may be done and could result in water quality benefits. However, activities such as grazing and equipment traffic over the top of the saturated buffer should be minimized during wet soil conditions. Ruts, soil compaction, or contact from machinery or vehicles can damage infrastructure and affect saturated buffer performance.

SYSTEM COMPONENT	POTENTIAL MANAGEMENT ACTIVITIES
Water Control Structure	Annual inspection and removal of debris. Adjusting depth settings may be required if located in flat topography.
Distribution pipe and tile outlet	Annual inspection such as checking for any failures (e.g. blow holes, suck holes) in the distribution pipe and erosion at the tile outlet.
Buffer Vegetation	Removal of woody vegetation near the distribution pipe. Mowing and/or haying as preferred.

WHAT TYPES OF VEGETATION SHOULD BE ESTABLISHED IN SATURATED BUFFERS?

The presence of vigorously growing perennial vegetation is essential for optimum nitrate removal within a saturated buffer. Select a species mix that is tolerant to moist soil conditions because the saturated buffer will raise the water table closer to the soil surface within the buffer during the spring and early summer when the tile outlet is flowing.

It is prudent to keep woody vegetation as far from the distribution pipe as possible due to concerns that their roots could plug the distribution pipe after some years. A non-perforated outlet pipe installed through the buffer will help prevent any issues resulting from roots plugging the drainage outlet.

Figure 6: *Views of saturated buffers one year after installation. White stand pipes are wells used to monitor the performance of the buffers for removing nitrate and are not required for typical installations.*

WHAT ARE THE COSTS OF INSTALLING A SATURATED BUFFER?

Costs of installing a saturated buffer will vary depending on the size of the control structure and the diameter and length of the distribution pipe. Control structures are commercially available and can be custom built. Anti-seep collars, which help prevent pipes and structures from being washed out by saturated soil conditions, are also strongly encouraged. Costs increase as the diameter of the tile outlet and its depth increases. A control structure for a typical installation should be approximately $1,000. Costs for the distribution pipe and installation will vary with pipe diameter and by the length of the saturated buffer but should range between about $1 to $3 per foot for 4" to 6" single wall plastic tile. The tile outlet pipe (Fig. 1) should consist of non-perforated pipe starting 20 feet upstream from the control structure and extending all the way to system outlet, which can range from $2 to$10 per foot depending on pipe size, length, and material. There will also be costs for backhoe work to locate and excavate the tile outlet, install and level the control structure, and install an anti-seep collar and non-perforated outlet pipe. Design costs will vary depending on local rates and if the project is completed through NRCS or state cost-share programs. Alternatively, a landowner can install their own system if they have access to a backhoe and trencher.

SYSTEM COMPONENT	TYPICAL COST	FACTORS INFLUENCING COST
Water Control Structure	$1,000/structure	Size of tile outlet pipe and depth of installation
Anti-seep collar	$150-$200/collar	
Distribution pipe	$1-$3/ft	Diameter and length of pipe, pipe material
Tile outlet pipe	$2-$10/ft	
Design, installation, and excavation work	Varies by location	

WHAT POLICIES OR REGULATIONS MIGHT APPLY IN INSTALLING SATURATED BUFFERS?

In general, there are no known regulations involved with installing a saturated buffer. When working with state or federal cost-share programs, policies vary, and landowners should consult with their local conservation professionals for details. Prior to installation, the appropriate 811 Call Center should be contacted to locate any underground utilities. If streambank modification is included as part of the project, landowners should consult their local conservation professionals about any applicable state or federal regulations.

HOW CAN I IDENTIFY APPROPRIATE SITES?

Several tools are available to help find suitable locations for saturated buffers. The first is the Agricultural Conservation Planning Framework (ACPF) *https://acpf4watersheds.org*. The ACPF uses spatial data on soils, land use, and topography, combined with knowledge of conservation effectiveness, to identify conservation practices to reduce nutrient discharge from small watersheds. The tool can be used to search for locations suitable for saturated buffers. While comprehensive, the tool takes some specialized software and time to master. The ACPF has been run on all stream segments in Iowa and the results are available at *https://www.nrrig.mwa.ars.usda.gov/st40_huc/satBuff.html*. This easy-to-use web resource can be used to locate possible sites within Iowa or to identify characteristics that would possibly limit saturated buffer effectiveness based on soil type and landscape characteristics. These tools are only the first step in determining suitable sites for saturated buffers. An onsite investigation needs to be made to confirm soil, landscape, and stream characteristics and to locate suitable tile outlets.

The USDA-NRCS Conservation Practice Standard 604 – Saturated Buffers – contains information on why and where the practice is applied, and it sets forth the minimum criteria that must be met during the application of that practice for it to achieve its intended purpose(s) and qualify for cost share. An excel spreadsheet is available to help in sizing the saturated buffer following NRCS Conservation Practice Standard 604. It can be found on the Illinois NRCS Engineering webpage *http://bit.ly/ilnrcseng* under "Saturated Buffer Design". Current national NRCS standards do not specify a given length of the saturated buffer based on the drainage area of the tile outlet. State specific requirements may vary from the national standard and should be followed.

CONCLUSION

A saturated buffer is an innovative practice that can remove substantial nitrate from field tile drainage water before it is discharged into streams or ditches. Saturated buffers also slow tile flow into surface waters by re-routing some of the water into buffers as slower-moving shallow groundwater. When properly sited and constructed so that the buffer is at a lower elevation than the field, saturated buffers do not require active management by farmers to perform properly.

This publication provides a broad overview of the benefits, costs, and other issues related to this practice. However, design and implementation of a saturated buffer will require much more information and site-specific analysis. Additional research is needed to address the remaining questions regarding this practice. Researchers across the Midwest are addressing these issues through a project called "Transforming Drainage", which conducts research, extension, and education to implement storage of drainage water and increase the resiliency of drained agricultural land.

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The authors of this publication are part of the **Transforming Drainage** project team, and the North Central Extension and Research Activity 217 (NCERA-217).

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FOR MORE INFORMATION

- The Transformation Drainage project, visit: *transformingdrainage.org*.
- Your local USDA Natural Resources Conservation Service office.
- Drainage contractors.

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