UNIVERSITY OF MINNESOTA | EXTENSION

Fields to Streams

MANAGING WATER IN RURAL LANDSCAPES

Part Two

Managing Sediment and Water

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Fields to Streams

PART TWO

Managing Sediment and Water

A publication of the University of Minnesota Water Resources Center

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Contents

Chapter One

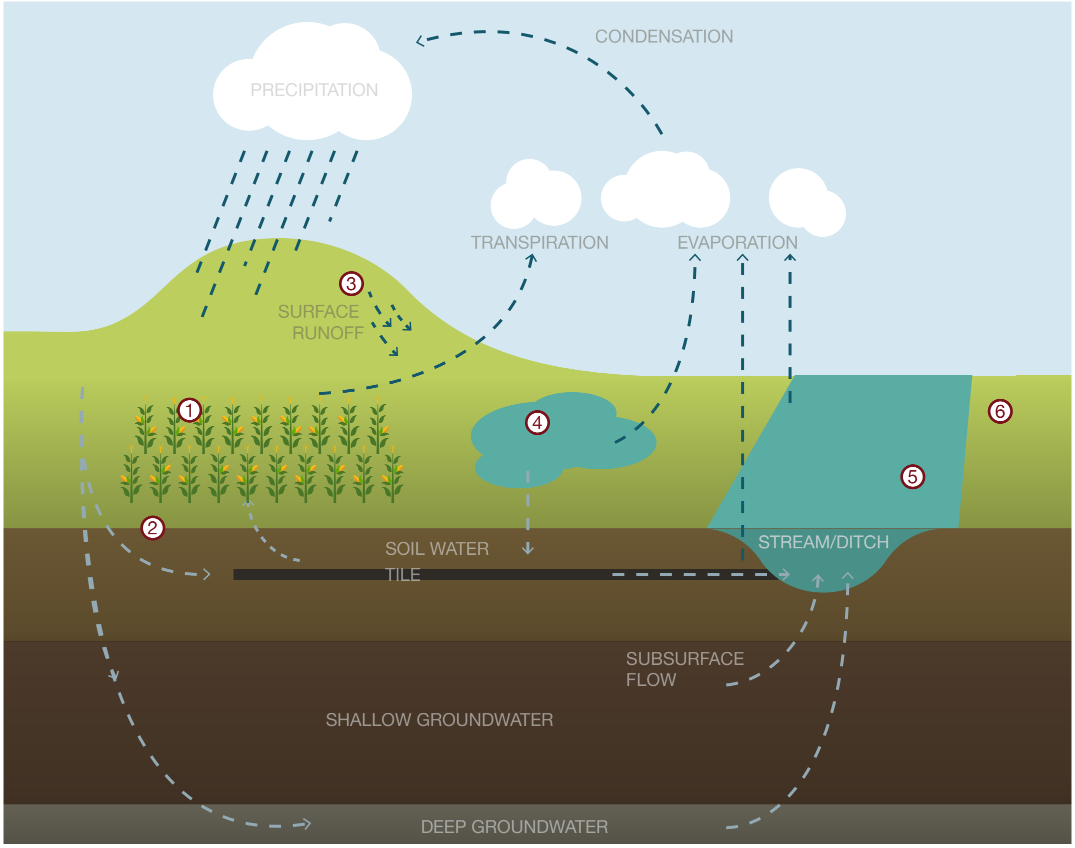
Fields to Streams: The Treatment Train

*For the detailed "how to" information for each practice, the relevant NRCS-USDA practice number (or numbers) is given for each practice found in the Field Office Technical Guide (FOTG), available on-line for each state and county (http://efotg.sc.egov.usda.gov/). Section IV of the FOTG provides detailed descriptions of practice design and operation. For some practices, the NRCS National Engineering Handbook is also referenced.

The Agricultural BMP Handbook for Minnesota includes descriptions of these practices along with effectiveness as determined by research in the Upper Midwest. See: http://www.mda.state.mn.us/protecting/cleanwaterfund/research/agbmphandbook.aspx

The second part of this document briefly describes land and water management practices* that protect streams and improve water quality by modifying water use and flows. These practices are most effective when they are combined in sequence, a "treatment train", along the entire path of a drop of water from where it falls on the land to where it either returns to the atmosphere in plant transpiration, or leaves the land as runoff. (See figures below.)

Individually or when combined, these practices often have multiple effects, including improved soil structure and water holding capacity, reduced channel erosion, better water quality and in-stream habitat, and reduced flooding. Ponds or wetland restorations for water storage and denitrification in an agricultural drainage system also improve drainage system efficiency. They dampen peak flows and thus reduce the size requirements for pipe and ditches downstream in the system. Practices that add perennial vegetation or diversify channel structure to reduce channel erosion also create habitat.



Source: ISG

Practices can be described by where they are located along the treatment train and what effects they have on hydrology. The numbers in the landscape diagram correspond to sections in the table of practices on the following page and to corresponding sections of the text that follow.

PRACTICES / EFFECTS	Increase spring transpiration	Increase infiltration	Increase soil water holding capacity	Reduce total water (and nitrogen) delivery	Increase denitrification	Reduce P and sediment delivery	Increase open water evaporation	Reduce peak flows	Reduce in-stream velocity
1. IN-FIELD: CROP AND SOIL MANAGEMENT									
Perennial crops, and crop rotations with perennials or winter annuals	●	●	●	●		●		●	
Cover crops	●	●	●	●		●		●	
Reduced tillage, contour cropping and residue management		●	●			●			
Compaction management		●	●						
Manure application[1]		●	●			●			
2. IN-FIELD: DRAINAGE WATER MANAGEMENT									
Alternative drainage design (depth, spacing, capacity)[2]				●				●	
Controlled drainage				●				●	
Alternative tile inlets		●				●		●	
3. IN-FIELD AND EDGE-OF-FIELD: SURFACE FLOW MANAGEMENT									
Grassed waterways	●	●		●		●		●	
Filter strips, contour buffer strips	●	●		●		●		●	
4. IN-FIELD AND EDGE-OF-FIELD: WATER STORAGE AND INFILTRATION									
Saturated buffers		●		●	●			●	
Restored and constructed wetlands		●		●	●	●	●	●	
WASCOBs, terraces, and detention basins		●		●		●		●	
Ponds and irrigation reservoirs				●	●	●	●	●	
Large retention basins		●		●	●	●	●	●	
5. DITCH CHANNEL: WATER RETENTION									
Structures for water control, including weirs and restricted size cluverts						●		●	●
Two-stage ditch with restricted size culverts						●		●	●
6. RIPARIAN AREA: RESTORATION AND PROTECTION									
Riparian vegetation	●	●			●	●			
Streambank, bluff, and shoreline protection						●			
Restore channel meanders					●				●

[1] Depends on the rate and method of application

[2] Effects relative to conventional drainage design

Practices selected for a specific treatment train differ by landscape type.

- Practices under the table heading “In-field: crop and soil management” are appropriate in most agricultural landscapes and therefore are at the beginning of most treatment trains. They manage water through increased spring transpiration, water infiltration, soil water holding capacity, and resistance to soil erosion.
- Treatment trains for tile drained landscapes might include one or more drainage water management practices coupled with tile water treatment and retention/detention in restored or constructed wetlands, ponds, irrigation reservoirs, or a modified ditch channel.
- Treatment trains applicable to more sloping landscapes could include grassed waterways, filter strips, buffer strips, terraces, and/or water and sediment control basins (WASCOBS).
- Riparian area restoration and stream channel protection are applicable at the end of treatment trains for most landscape types.

Because treatment trains need to be designed for local landscapes, climates and cropping systems, conservation staff are encouraged to develop and share examples that fit their watershed circumstances.

The costs for the practices differ considerably with size, location, contractor, and other factors. ISG has provided estimates for contractor work in 2015, based on their experience. The cost ranges are listed at the end of most of the practice descriptions except for crop management practices.

Note that the practices described in this document were selected for their contribution to water volume and flow management. Many of them have other benefits, including nutrient and sediment removal, provision of wildlife or aquatic habitat, and others. This document does not describe other practices that are important for reducing the concentration of pollutants but have no effect on water volume, such as nutrient management.

Chapter Two

In-Field Practices: Crop Management

Crop management activities that affect runoff timing and volumes include the selection of crop types and their rotation, tillage and residue management, machinery traffic as related to soil compaction, and manure management. These are classified by USDA-NRCS as prevention practices and are applicable across most agricultural landscapes.

Changes in crop management modify stream flows by:

- altering the timing and amount of water removed from soil by plants through transpiration.
- changing the amount of water that either runs off the surface or infiltrates the soil.
- changing the soil water holding capacity through changes in soil structure and soil organic matter.

2.1 PERENNIAL PLANTS

Perennial grasses, forage legumes, and woody vegetation begin transpiration earlier in the spring and continue later in the fall compared to summer annuals like corn and soybeans. They are able to remove some of the excess spring precipitation, reducing tile flows (Part 1, Chapter 7) and stream flows in the highest rainfall periods. They increase infiltration by removing water through transpiration, and by enhancing soil structure by minimizing soil disturbance and increasing soil organic matter. Increased soil organic matter increases soil water holding capacity. Perennial plant buffers and filter strips (Section 4.2), when strategically placed, will significantly reduce and filter runoff from summer annuals like corn and soybeans (Hernandez-Santana, 2013). In addition to enhancing water use and infiltration, the extensive root systems of most perennials directly resist soil erosion throughout the year.

Source: L. Everett, UM

Perennial forage crop beside a field of soybean stubble in Iowa on April 6, 2015. The forage is transpiring while the corn crop has not yet been planted.

2.2 COVER CROPS

NRCS Practice Standard 340, Cover Crop

Cover crops, especially those that over-winter, affect stream flows in similar ways to perennials in that they transpire in the fall and spring when summer annuals are not active, increase infiltration, and can maintain or increase soil organic matter if sufficient cover crop growth is allowed. They have less of an effect on runoff than established perennials because they take time to establish each year. Cover crop living root systems in the fall and/or spring directly resist soil erosion. In order to meet cover crop establishment and management challenges of the Upper Midwest, intensive research is under way addressing cover crop species, planting techniques, and termination, as well as nutrient management for the following crop. For current information see the most recent Extension bulletins.

Source: L. Everett, UM

Cover crop drill seeded in the fall and growing beside a field of tilled corn residue in Iowa on April 6, 2015. The soybean crop will not likely be planted for another month and the canopy will not be closed until late June.

2.3 CROP ROTATIONS

NRCS Practice Standard 328, Conservation Crop Rotation

Each crop in a rotation will affect the amount and timing of water reaching a stream through the timing and amount of its transpiration, and its effect on soil organic matter and structure. Winter annuals like winter wheat and winter rye grow quickly in the spring, removing more water in that excess precipitation period than summer row crops. Perennials in the rotation reduce excess water in the spring and fall as described above.

2.4 MANURE APPLICATION

Incorporation or injection of livestock manure increases soil organic matter and soil particle cohesion, increasing water infiltration and reducing soil erosion (Gessel et al 2004). However, surface application of manure without incorporation or repeated application of manure above crop nutrient needs can result in more phosphorus in runoff.

2.5 TILLAGE AND CROP RESIDUE MANAGEMENT

NRCS Practice Standard 329, Residue and Tillage Management: No-Till/Strip-Till/Direct Seed
NRCS Practice Standard 345, Residue and Tillage Management: Mulch Till

The effects of tillage and crop residue management on stream flows are complex and interact closely with crop rotations, soils, and climate. Tillage can impede infiltration, both by degradation of soil structure and by compaction below the tilled zone. It increases oxidation of soil organic matter, reducing its content in soils over time. However, corn is sensitive to cold wet soils in the spring found in the flatter and poorly drained glacial till and lacustrine soils of south central and southwest Minnesota. Tillage and reduced residue increase surface soil temperature and evaporation in the spring. Strip tillage or full width mulch tillage permit corn to germinate and grow earlier and provide more consistent yields in poorly drained soils. Soybeans respond less to tillage in these areas. (DeJong-Hughes et al 2007, Randall et al 2002b, Randall et al 2005). Research has shown that tillage is not essential for high yields for corn-soybean rotations in well-drained soils of southeast Minnesota (Randall et al 2002a), where higher slopes increase the risk of soil erosion with tillage.

Source: ISG

Strip tillage creates a tilled strip for the crop row, but leaves the crop residue intact between the rows for soil protection.

2.6 COMPACTION MANAGEMENT

Restricting machinery axle weight, especially when soil moisture content is high, preserves soil structure and prevents compaction (DeJong-Hughes et al 2001). Use of deep rooting cover crops can alleviate tillage-zone compaction.

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Randall GW, Vetsch J. 2005. Optimum tillage systems for corn and soybean production and water quality protection in South Central Minnesota—Minnesota River Basin. University of Minnesota Bulletin. http://www.extension.umn.edu/agriculture/tillage/optimum-tillage-systems-for-corn-and-soybean/

Randall GW, Wagar TL, Senjem NB, Busman LM, Moncrief JF. 2002a. Tillage best management practices for water quality protection in Southeastern Minnesota. University of Minnesota Bulletin. http://www.extension.umn.edu/agriculture/tillage/tillage-best-management-practices-for-water-quality-protection/index.html

Chapter Three

In-Field Practices: Drainage Water Management

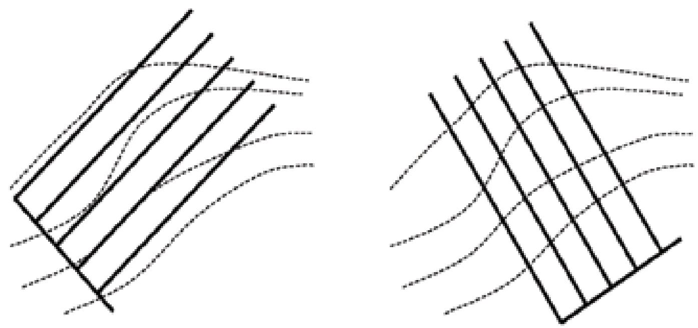
3.1 DRAINAGE DESIGN

Designing an agricultural field drainage system involves choices about two components: the drainage rate or capacity, and the system layout.

SYSTEM LAYOUT: The system layout determines the potential now or in the future to use it for controlled drainage and/or subsurface irrigation. For both options laterals need to be aligned with field contours (left diagram below) rather than running up-and-down slopes (right diagram below) in order to minimize the number of control structures required to manage the water table. Because drainage infrastructure will last for decades, using a design that provides the most options for water management is a good low cost investment. Section 3.2 addresses some of these options.

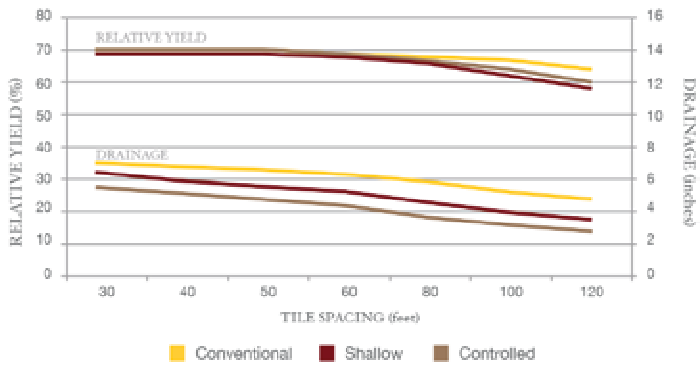
DRAINAGE CAPACITY: The drainage capacity depends on spacing, depth, and size of tile. The optimal design provides adequate but not excessive drainage to enable good crop growth under a variety of weather conditions, but does not flood neighboring properties or overload downstream tile mains, ditches and streams. Designing for optimal rather than higher drainage rates will have little impact on yield but can have substantial downstream effects. NRCS and the University of Minnesota both list a drainage coefficient of 3/8 to 1/2 inch water removal in 24 hours for drainage of mineral soils if there are no surface inlets (NRCS Practice Standard 606, Subsurface Drain, and Wright et al, 2009). For additional design specifications see both the NRCS practice standard and University of Minnesota Extension drainage publications at http://www.extension.umn.edu/agriculture/water/publications/

The impacts of drainage design depend on the specific soils and climate of the site. **Shallower drains, wider spacing, and managed drains** result in less water being drained and less nitrate loss since nitrate loss is generally proportional to drainage discharge. However, there is risk of yield loss when spacing exceeds a threshold determined largely by soil type. A simulation study (graph below) based on six years of field data from Waseca, Minnesota on a Webster silty clay loam found that for a drain spacing of 60 ft or less, changing depth and spacing had little impact on yield, but costs and nitrate loss increased as tile became deeper and more closely spaced. The authors concluded that both shallow drainage (3 ft vs 4 ft depth) and controlled drainage may reduce annual drainage discharge and nitrate losses by 20–30%, with minor crop yield changes ranging from a 3% yield decrease to a 2% increase, depending on lateral drain spacing. For a given drainage spacing, controlled drainage was more effective than shallow drainage at reducing water and nitrate-N losses, while maintaining yields.



Source: Wright et al. 2009

Alignment of field laterals



Source: Date from Table 6 or Luo et al. 2010

Relative corn yield and drainage simulated under a range of drain tile spacings and depths calibrated for Waseca, MN. Conventional drainage is 4 ft. depth. Shallow is 3 ft. Controlled drainage is 6 inch water table depth through March, 4 ft. through April, and 2 ft. May through early November.

3.2 CONTROLLED SUBSURFACE DRAINAGE

NRCS Practice Standard 554, Drainage Water Management
NRCS Practice Standard 587, Structure for Water Control

Controlled subsurface drainage is a practice used to manipulate the groundwater elevation in agricultural fields with 0-1% slopes. It is similar to a traditional drainage system; however the outflow is intercepted by a water control structure which controls the water table elevation. This structure contains an inlet and outlet tile with removable stop logs placed between them to effectively control the water table elevation. The objective is to both retain water for use later in the season, and to reduce total water and nitrogen leaving the system. See Frankenberger et al, 2007.

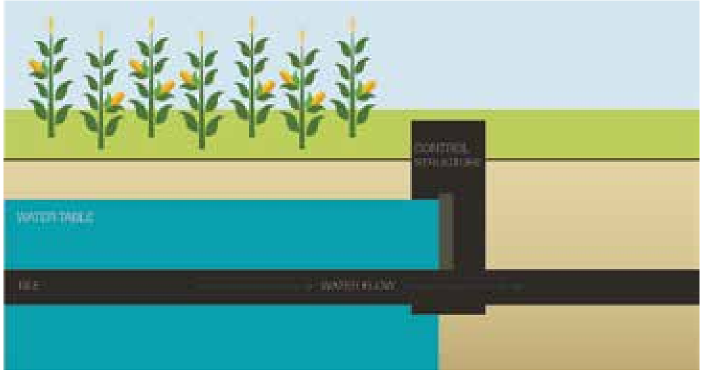
WHERE

Agricultural fields of slopes 0-1% where one control structure can control the water table of an average of ten acres or more of a tile drained field.

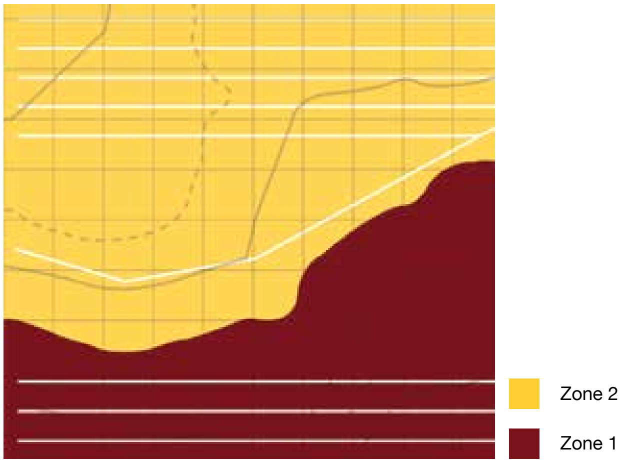
EFFECTS

- Reduced total water delivery through water table management and appropriate design capacity
- Reduced peak flows, flooding, and downstream channel erosion
- Reduced nitrogen delivery from subsurface drainage through water retention at appropriate times
- Adequate drainage in the spring for crop establishment while conserving water for later in the season, which in some years will increase crop yield

Typically the control structure is adjusted to allow the water to drain during the planting and harvesting months while during the growing season the water table is held higher in the ground to allow for better crop growth and associated reduced volume of outflow and reduced nutrient transport. In this system, field tile is placed three to four feet below the ground surface. The control structures allow water to either remain high in the ground or to be drained when necessary. A control structure can manage the water in the ground for a difference of one to two feet of elevation change. For areas where greater elevation changes occur, additional control structures are needed. Areas appropriate for controlled subsurface drainage contain an average of ten acres over an elevation change of one to two feet. To maximize drainage area controlled by one structure, the laterals must be installed parallel to the field contour.



Source: ISG - Adapted from diagram from Farm Progress



Source: Sands, 2010

Drainage water management design calls for dividing the field into water control/management zones, aligning laterals with the field contours, and using control structures. Annual subsurface flow and nitrate reductions from 10% to 50% have been measured.

Water quality benefits associated with controlled subsurface drainage include overall volume reduction of subsurface drainage, an increase in mid-season soil moisture which allows for more plant growth and higher yield potential, and a reduction in nitrogen delivery with the reduction in water volume.

COST

$3,000 *to* **$5,000** for installed water control structure

$1,000 *to* **$1,500** per acre, for tile
(compared to **$600** *to* **$900** for tile not designed for control)

SUB-IRRIGATION

In addition to storing water in the soil profile for later use, a controlled drainage system can be designed (usually with closer pipe spacing) to also accept water back into the system for sub-irrigation later in the season, providing there is a water source. Storing excess water from spring and early summer drainage for later supplemental irrigation (Section 5.7) can both increase yields and reduce downstream flows and nitrate delivery. See Evans and Skaggs, 1996, for design and operation of a combined controlled drainage and sub-irrigation system. Research on storage for irrigation is being carried out by a consortium of Midwest universities, including the University of Minnesota.

COST

Costs of sub-irrigation installation depend on water source, pump, and density of tile needed for the site soil properties.

3.3 ALTERNATIVE TILE INLETS

Alternative tile inlet structures replace open surface intakes that are flush with the ground. They include perforated risers, gravel inlets, dense pattern tile within the associated low area, reduced side intake sizes, trash grates, grade stabilization, and any other variation of the above. They are designed to temporarily pond water around the inlet structure to increase the detention time and reduce the peak flow rates of the surface water as well as settle out sediment and sediment-bound phosphorus.

WHERE

Ditch side inlets, field depression tile inlets, terraces, water and sediment control basins.

EFFECTS

- Reduced peak flows
- Reduced sediment and phosphorus delivery to streams

The added detention time from alternative tile inlets allows for the sediment to settle out on the surrounding landscape prior to discharging through the inlet structure. This prevents sediment from further entering drainage systems and also controls flow rates into surface drainage systems which reduces sloughing and erosion in nearby waterways. The flow restriction that creates the detention differs with the type of inlet. With the raised slotted inlet, it is from the slotted riser itself. With a dense subsurface tile structure, e.g. coiled inlet, the soil is the restriction. With a rock or gravel inlet, the restriction is the size of the pipe leading away from the rock inlet.

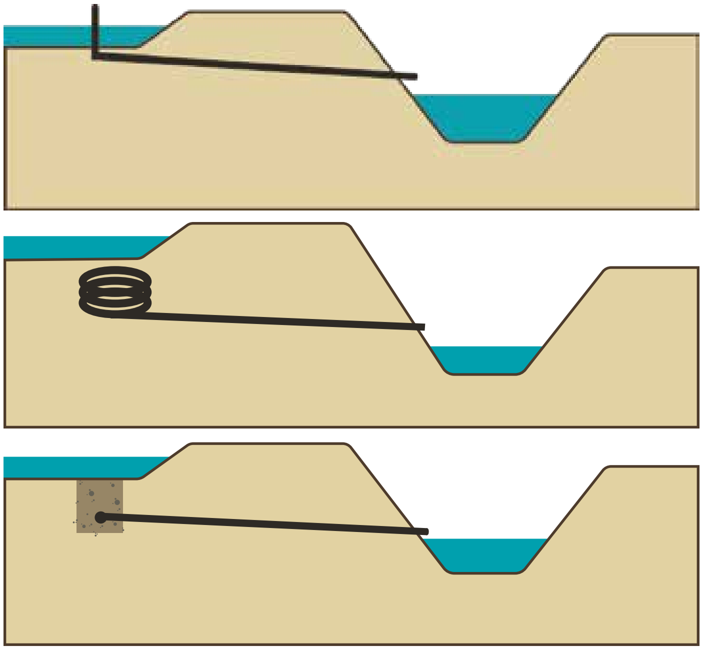
Alternative tile inlets are typically installed in low areas near a drainage ditch where water naturally drains and ponds. They can also be placed where large surface flows overtop a ditch bank and cause erosion. Recently, alternative inlets have been used to replace old and damaged traditional open inlets in depressional areas due to their water quality benefits. Additional design details can be found in the NRCS Conservation Practice Standard 980.

COST

$1,200 *to* **$2,000** installed, including the pipe to the outlet

Source: ISG

Raised Surface Inlets



Source: Sands, 2010

Alternative ditch side inlet designs including a slotted riser (top), coiled subsurface tile (middle), and rock/gravel inlet (bottom)

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RESOURCES

Ag Drainage Management Coalition www.admcoalition.com

Carlson B, Sands G. 2013. Evaluating a Subsurface Drainage Project and Its Alternatives. University of Minnesota Extension FO-08679. http://www.extension.umn.edu/agriculture/water/publications/pdfs/carlson__sands_evaluating_drainage_2013.pdf

The University of Minnesota Extension drainage website, "The Drainage Outlet", http://www.extension.umn.edu/agriculture/water/drainage-science.html includes information about the following events and links to many publications:

- Ag Drainage Design Workshops
- Annual IA-MN-SD drainage research forum

Chapter Four

In-Field and Edge-of-Field Practices: Surface Flow

Grassed waterways, filter strips and buffer strips are effective practices for infiltration, transpiration, and filtration of field runoff, as well as for protecting the underlying soil from erosion. Buffers stabilize stream and ditch banks by maintaining soil cohesion and removing water from the banks. They must be designed and sized to treat or safely convey the expected flow volumes from their contributing areas. See the NRCS Field Office Technical Guide and associated references for design information.

4.1 GRASSED WATERWAYS

NRCS Practice Standard 412

Grassed waterways are vegetative drainage swales through agricultural land that provide a means for concentrated flows to drain from the surface while minimizing erosion.

WHERE

Paths of concentrated surface flows in agricultural fields.

EFFECTS

- Reduced gully erosion
- Increased infiltration
- Reduced surface flow rates
- Water removal by transpiration

Grassed waterways are installed throughout a watershed on fields with concentrated flows to prevent gully erosion. They are also used to convey runoff from terraces and diversions to nearby drainage channels. Grassed waterways reduce surface flow rates and act as a filter for nutrients. As with any perennial vegetated area receiving field runoff, a build-up over years of sediment in the receiving edge can prevent runoff from entering the waterway and must be periodically reshaped to restore flow into the waterway or filter.

COST

$2,000 *to* **$3,000** per acre for shaping and seeding

Source: NRCS-USDA

4.2 FILTER STRIPS AND CONTOUR BUFFER STRIPS

NRCS Practice Standard 393 for filter strips
NRCS Practice Standard 332 for contour buffer strips

FILTER STRIPS are an area of vegetation planted between fields and surface waters to minimize organics, nutrients, and sediment in runoff from entering nearby surface waters. They also reduce runoff velocity and erosion near surface waters by developing sheet flow throughout the strip. Typical plant species in filter strips include stiff, upright stemmed vegetation such as Big Bluestem, Canada Wildrye, Switchgrass, and other native prairie grasses.

WHERE

Field edges, property lines, or along water channels at the top of the bank. In Minnesota, strip widths must be at least one rod (16.5 feet) along ditches within the benefited area of public drainage systems and 50 feet where adjacent to public waters.

CONTOUR BUFFER STRIPS function like buffer strips, but are narrow strips alternated with crops planted on the contour within the field. The objective is to slow, filter, and infiltrate surface flows that are moving down the slope through the crop fields.

WHERE

Sloping annual crop fields.

EFFECTS

- Reduced sediment and phosphorus delivery to ditches and streams resulting from filtration
- Reduced runoff volume with increased infiltration and increased transpiration
- Reduced bank sloughing resulting from reduction of soil water saturation and increased soil cohesion

Experiments with well-established prairie strips at the base of slopes in corn fields in Iowa delayed the time of peak runoff and reduced runoff volumes by more than 50% when occupying 10% of the watershed. (Hernandez-Santana, 2013)

COST

$1,500 *to* **$2,000** per acre for native prairie

$500 *to* **$1,000** per acre for brome grass

Source: Minnesota Pollution Control Agency - Willmar, MN

Filter Strip

Source: NRCS-USDA

Contour Buffer Strip

REFERENCES

Hernandez-Santana V, Zhou X, Helmers M J, Asbjornsen H, Kolka R, Tomer M. 2013. Native prairie filter strips reduce runoff from hillslopes under annual row-crop systems in Iowa, USA. Journal of Hydrology 477: 94-103.

Chapter Five

In-Field and Edge-of-Field Practices: Water Storage and Infiltration

Stream protection in regions with extensive row crop agriculture will require storage of runoff and drainage water during peak flow periods to reduce the high flows that cause the most streambank, bluff, and ravine erosion. The water is detained for slow release over hours, days, or weeks, or is retained for later uses like supplemental irrigation. As described earlier, spring and early summer are the periods that require the most storage, since row crops are not yet established with full canopy transpiration. This chapter highlights some water storage practices, coupled in some cases with infiltration, that can be introduced into a treatment train. Siting of these practices can be initiated by the landowner or suggested through a watershed planning process as discussed in Chapter 8.

5.1 SATURATED BUFFER

NRCS Practice Standard 739

A saturated buffer or vegetative subsurface outlet is an alternative drainage tile outlet in which tile drainage water seeps beneath buffer areas of perennial vegetation via a subsurface distribution pipe prior to entering a drainage ditch or stream. The purpose is to reduce nitrate in tile water via denitrification and plant uptake, and to reduce peak flows associated with typical tile drainage outlets.

WHERE

Outlet of a tile system to a drainage ditch with a vegetated buffer. The soils and topography must be capable of maintaining a raised water table in the buffer adjacent to the nearby channel without adverse effects to channel banks or raising the water table in the adjacent crop land.

EFFECTS

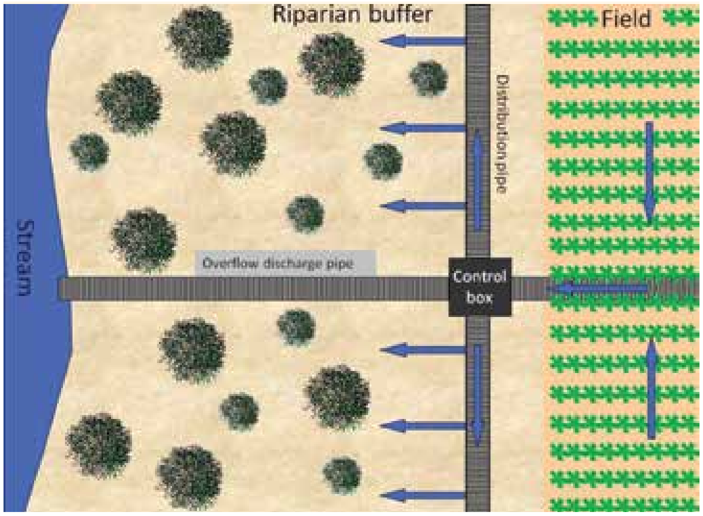
- Reduced nitrate delivered to ditches and streams
- Reduced peak runoff and total runoff with water detention and transpiration

The design of a saturated buffer includes installing a structure for water control and subsurface distribution piping capable of diverting drainage system water to create a zone of soil saturation near the end of the tile system. The structure diverts water to the vegetative buffer strip via perforated tile during normal flows while allowing peak flows to travel directly to the ditch or stream through a non-perforated pipe once the distribution pipe is at capacity. Additional design criteria for saturated buffers can be found in the NRCS Practice Standard 739.

COST

$3,000 *to* **$5,000** for installed water control structure

$10 *to* **$12** per foot, for installed tile



Source: Dan Jaynes, USDA-ARS

Top view diagram of a saturated buffer.

5.2 WETLAND RESTORATION

NRCS Practice Standard 651, wetland restorations

A wetland restoration is the reestablishment of natural hydrology and/or native vegetation to a former or degraded wetland that has been drained, farmed or otherwise modified.

WHERE

Former or degraded wetlands, often found in landscapes with subsurface and/or surface drainage systems.

EFFECTS

- Increased water storage leading to reduced peak flows, flooding, and channel erosion downstream
- Filtration/retention of sediment, pesticides, nutrients, and bacteria
- Nitrate removal by denitrification
- Restored habitat

Restored wetland vegetation usually consists of a mix of native hydrophytic (water-loving) vegetation including grasses, sedges, rushes and forbs in a basin or ponded area (wet meadow or emergent wetland). Mixtures of native prairie grasses and forbs are also incorporated in the adjacent upland areas.

In addition to improved water quality, wetlands are often restored to provide wildlife habitat. Wetland ecosystems are home to numerous species of birds, amphibians, and also provide habitat for small game and other species in the adjacent upland areas.

BALANCING GOALS

Ecological goals of wetland restorations may conflict with goals of re-establishing hydrologic and water quality functions of a wetland, especially in agricultural landscapes. High nutrient levels often lead to reduced biodiversity and dominance by reed canary grass in wet meadows or cattails in the emergent wetland area. Frequent extreme variations in water levels, peak flow rates, and sediment and nutrient loaded water entering the wetland reduce some ecological functions like waterfowl nesting. The goals for each restoration will determine whether or not to include treatment of agricultural runoff or drainage water. Where agricultural runoff contains substantial sediment and nutrients, constructed wetlands may be more appropriate. (See section 5.3)

Source: ISG

Restored deep wetland/lake - Blue Earth County, MN

Source: C. Lenhart, UM

Restored shallow wetland - Blue Earth County, MN

REMAINING WETLAND TYPES

In southern and western Minnesota historically there were vast areas of wet prairies with shallow prairie pothole basins and deeper marshes and lakes interspersed, all providing water storage via surface ponding and soil water. Most of the wet prairies were drained for agriculture in these regions leaving only the deeper marshes (three feet deep or more) and lakes remaining. In the past 30 years, hundreds of small prairie pothole basins restored through the Wetland Reserve Program and other initiatives have added back some of the lost water storage. Most of the water storage remaining in the agricultural regions of Minnesota today lies in the marshes and lakes and not the shallower wetlands types since the wet prairies have been largely eliminated by drainage.

FUNDING

Wetland restorations are commonly funded through programs such as RIM-WRP (Reinvest in Minnesota-Wetlands Reserve Program) or CREP (Conservation Reserve Enhancement Program) in which purchased easements or long term rental contracts compensate landowners for setting land aside for the restorations. Recently, many wetlands have been restored by private land owners to sell as wetland mitigation credits (wetland banking) as either Standard Wetland Credits or Agriculture Wetland Credits. An individual land owner is responsible for up front design, construction, and monitoring costs, but can sell the credits through the wetland banking program to provide mitigation for wetland losses from other permitted projects.

WHERE TO LOCATE WETLAND RESTORATIONS

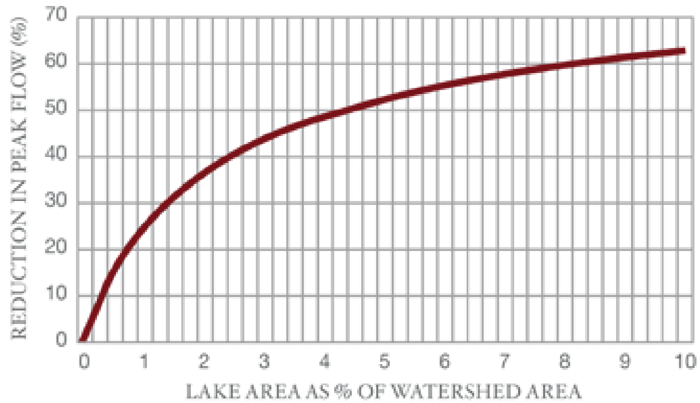
Wetlands are typically restored in an existing basin where minimal excavation and earthwork is necessary to pond and store water. This may be an old basin, wetland, or lake that was once drained for farming practices. It may also be a low area in relation to the surrounding landscape that consistently has flooding and crop damage due to the natural geometry of the watershed. Wetlands can be restored throughout a watershed, but are suggested in areas where there is a ratio of watershed area to wetland ponded area of 6 to 1 or greater to provide sufficient hydrology to the wetland.

REDUCTIONS IN PEAK FLOWS

Based on a USGS equation for southern Minnesota flooding, by reestablishing only one to two percent of a watershed area as water storage, downstream flooding and high peak flow rates can be significantly reduced (see graph).

COST

$12,000 *to* **$17,000** per acre



Source: USGS equation for south central Minnesota by Lorenz et al. 2010

Percent reduction in ten year recurrent peak flows in relation to lake surface area as a percent of total area in a watershed.

5.3 CONSTRUCTED WETLAND

NRCS Practice Standard 656, constructed wetlands, and
Farm Service Agency Conservation Reserve Program (CRP) Practice Treatment CP-39

Constructed wetlands, like retention basins, are typically designed to store a specific amount of water, but may be primarily focused on nutrient removal.

WHERE

At the outlet of a small watershed or drainage system where the topography and soils permit construction of a retention structure and/or excavation, and establishment of wetland vegetation without impeding drainage of nearby crop fields.

EFFECTS

- Reduced sediment, nitrate and phosphorus delivery to streams
- Reduced peak flows, flooding, and downstream channel erosion

Nutrient removal in a constructed wetland is enhanced by providing a longer retention time compared with a detention basin, with a minimal fluctuation in water level. This provides adequate time for denitrification and for the vegetation to absorb passing nutrients while also protecting the vegetation from severe fluctuations in water level. Constructed wetlands may take less space than a wetland restoration and can be placed in a location that is favorable to farmers. Constructed wetlands are typically designed for a smaller watershed due to the ecological impacts on the vegetation, limited space available, and they also may require more maintenance than a wetland restoration due to sediment accumulation.

COST

$4,000 *to* **$7,000** per acre foot of storage

$15,000 *to* **$20,000** for a stucture for water control for a basin with storage between 5 and 50 acre feet

Source: Iowa Department of Agriculture and Land Stewardship

Constructed wetland, Iowa CREP

5.4 WATER AND SEDIMENT CONROL BASINS (WASCOBs)

NRCS Practice Standard 638

Water and sediment control basins (WASCOBs) are an earth embankment placed perpendicular to the water flow direction on a moderate to steep hillside of agricultural area. The primary goal of WASCOBs is improve the ability to farm steep sloped areas of farmland by reducing gully erosion.

Source: NRCS-USDA

WHERE

Typically placed to intercept concentrated flow in areas of moderate to steep slopes.

EFFECTS

- Reduced soil erosion
- Reduced peak flows
- Reduced sediment and phosphorus delivery

WASCOBs are placed in areas that experience gully erosion and steep side slopes. They are designed to temporarily pool water on the hillside behind the embankment, thus reducing peak flow rates and soil erosion. Secondary benefits of WASCOBs include sediment and nutrient removal.

WASCOBs range in size and are dependent on several design factors including existing landscape slopes, required fill height, soil types, and severity of the gully. The outlet of a WASCOB is typically a vertical drop inlet which is connected to a subsurface drainage tile. WASCOBs can be placed either as a single unit or in a series similar to terraces.

COST

$100 *to* **$150** per linear foot for construction of berm and seeding

$1,200 *to* **$2,000** for alternative tile inlet

+ plus cost of tile outlet

5.5 TERRACE

NRCS Practice Standard 600

A terrace is an earthen embankment or ridge placed parallel with the contours of a moderately to steeply sloped farm field. The primary goal is to intercept surface water and prevent soil erosion throughout the area by reducing slope length and flow accumulation, diverting water into subsurface tile or grassed waterways.

WHERE

Moderately to steeply sloping crop fields where soil erosion is a risk.

EFFECTS

- Reduced soil erosion
- Reduced sediment and phosphorus delivery
- Reduced peak flows

Like a WASCOB, terraces temporarily pond water behind the embankment and slowly outlet the water to either a subsurface tile or to a grassed waterway. Terraces also provide sedimentation, reduce flow rates, and remove nutrients from surface water. Terraces are typically built in a series parallel to each other and are stepped up steep side slopes. Terraces are also beneficial to agricultural production as they prevent erosion, thus holding topsoil on the landscape and preventing it from eroding downstream.

While the overall function of terraces and WASCOBs are similar, they vary in design and placement. Terraces are longer, cover a much larger area, and are installed in series with each other. They typically run for the full length of a steep sloped area or hillside where a WASCOB is primarily one specific area where gully erosion occurs. Terraces are used to reshape the landscape to improve the agricultural farmability and production on steeply sloped areas.

COST

$100 *to* **$150** per linear foot for construction of berm and seeding

$1,200 *to* **$2,000** for alternative tile inlet

+ plus cost of tile outlet

Source: Farm Progress

5.6 GRADE STABILIZATION STRUCTURE

NRCS Practice Standard 410

A Grade Stabilization Structure is used to control the grade and head cutting erosion in natural or artificial channels with a combination of earth embankments, mechanical spillways and full-flow or detention-type structures. When designed for detention, they are effective at reducing peak flows.

WHERE

They are installed where the concentration and flow velocity of water require structures to stabilize the grade in channels or to control gully erosion. Terraces and WASCOBs are generally placed in fields to prevent erosion, whereas grade stabilization structures are usually placed outside the field areas at the head of ravines and gullies or at ditch side inlets.

EFFECTS

- Reduced soil erosion
- Reduced sediment and phosphorus delivery
- Reduced peak flows

COST

Highly dependent on shape of topography, size of dam, and capacity of structure for water control.

Source: Goodhue Soil and Water Conservation District, Minesota

Grade stabilization structure in the Zumbro River Watershed stops progression of a large gully, and provides stormwater detention and retention as well as sediment storage.

5.7 RETENTION AND DETENTION BASINS

The applicable NRCS practice standard depends on the size, location and additional features required of the project. Options might include Sediment Basin (350), Pond (378), Grade Stabilization (410), or Dam (402)

Retention and detention basins are excavated or ponded areas with an engineered outlet designed to store water during a rain event. Both collect runoff and release it at a controlled rate to reduce peak flows from a drainage system.

- A detention basin is designed to temporarily store water during a rain event and release all the stored water at a controlled rate.
- A retention basin is designed to store a set amount of water and typically will contain a permanent pool of water in the basin. It will typically have one controlled outlet to the basin while a secondary outlet will serve large rain events.

Both types function by trapping sediment and associated nutrient laden water for a sufficient time, allowing the particles to drop out of suspension and allow for nutrient uptake and removal in vegetative areas.

WHERE

At the outlet of a small watershed, or in the middle or at the outlet of a drainage system.

EFFECTS

- Reduced peak flows and total flows
- Reduced soil erosion
- Reduced sediment, nitrate and phosphorus delivery

Most detention and retention basins in agricultural drainage systems are sized to treat a watershed between 300 and 3,000 acres. Therefore they are typically located at or near the end of a drainage system, but can be placed near the middle of a large drainage system to dampen peak flows, reducing flooding as well as size requirements for pipe and ditches downstream in the system. An example is County Ditch 57 in Blue Earth County, Minnesota where a large detention basin was placed in the middle of the system to reduce flooding and pipe and ditch size requirements downstream in the system. Dependent on the watershed size, a typical basin will range between three and five acres in size and will be excavated between five and ten feet deep. The final design is determined on the overall goals of peak flow reduction and detention time. Studies have shown that reducing peak flows from an agricultural drainage system have had a linear effect on reducing the sediment and nutrient loading from the water. Peak flow reductions range between 60 and 80 percent (see figure below). With this reduction of peak flows, sediment reduction can range between 40 and 60 percent while phosphorus and nitrogen

Source: ISG

Detention Basin, Ditch 57 - Blue Earth County, MN

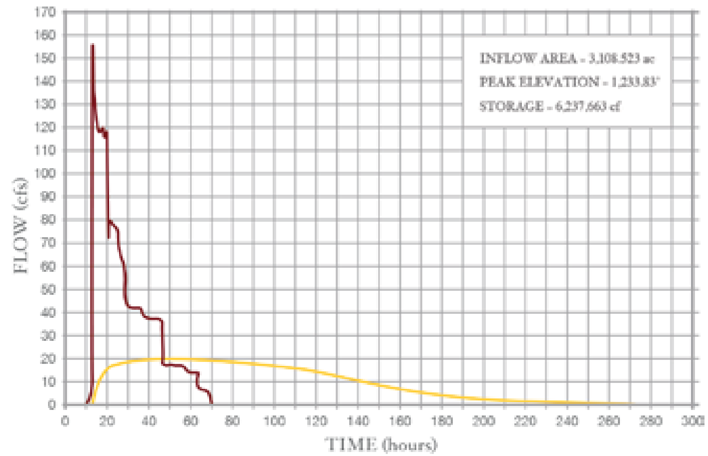
Source: ISG

Retention Basin, Ditch 57 - Blue Earth County, MN reductions range between 50 and 70 percent (ISG results for CD57 improvement, Blue Earth County, Minnesota).

Retention and detention basins can achieve a similar storage capacity and retention time as a wetland restoration by excavating a deeper basin in a much smaller area. Where a large watershed consists primarily of agricultural land, an excavated basin may be preferred over a wetland restoration due to the ecological conflicts that may occur with agricultural drainage and wetlands. An engineered basin can tolerate more variation in hydrology such as an increase in peak flow rates entering the basin, sudden fluctuation of maintained water elevation, and high sediment and nutrient loaded water. Therefore engineered basins may be preferred over a wetland where the majority of the drainage water flows directly through the storage area.

COST

Highly dependent on shape of topography, size of dam, and capacity of structure for water control.



Source: ISG

Inflow (maroon) and outflow (gold) hydrographs from a detention basin in Blue Earth County, Minnesota, designed to reduce downstream damages and infrastructure requirements in a large drainage system.

5.8 PONDS AND IRRIGATION RESERVOIRS (DAMS)

NRCS Practice Standard 378, ponds
NRCS Practice Standard 402, dams

The purpose of a farm pond is to provide water for livestock, fish and wildlife, recreation, fire control, develop renewable energy systems, and other related uses, and to maintain or improve water quality. They are formed by excavation and/or embankments and are usually of a smaller scale.

WHERE

At the outlet of a small watershed. The planned use of the pond water will determine the placement of the pond as it relates to the land use in and quality of the water from the contributing watershed.

NRCS Practice Standard 402 for Dams is targeted for larger scale uses, such as providing water for irrigation. Drainage and/or runoff water impounded during the spring and early summer would be available for sprinkler or sub-irrigation application during periods of drought stress later in the season (Baker et al, 2012).

WHERE

Outlet of a drainage system or small watershed.

EFFECTS

- Water available for livestock, fish, wildlife, and/or crop irrigation
- Reduced sediment, nitrate and phosphorus delivery
- Reduced peak flows and total flows if water is removed for livestock or irrigation

COST

Highly dependent on shape of topography, size of dam, and capacity of structure for water control.

5.9 LARGE SCALE IMPOUNDMENTS

Large scale impoundments are created to provide a large amount of storage and reduce downstream flooding. Large dikes are constructed around the perimeter of the impoundment area with engineered outlet structures to control the exiting flow rates. Water from nearby drainage systems is diverted into the impoundment and stored for a period of time and is released over time to minimize downstream peak flows and flooding.

WHERE

In watersheds where significant water storage is needed to reduce peak flows and flooding. Typically the impoundment area varies between 1,500 and 2,500 acres and is located in naturally occurring low lying areas such as floodplains, drained basins, and adjacent farmland near a drainage system or watercourse.

EFFECTS

- Reduced peak flows and total flows
- Reduced sediment, nitrate and phosphorus delivery to streams and rivers

Some large impoundments are designed as sequentially filling pools so that in years when full capacity is not needed, farming can still take place in the un-filled pools. In addition to flood storage, many secondary benefits are achieved such as sedimentation, nutrient uptake, peak flow reductions, and an increase in agricultural production. Habitat enhancement is also provided to fish, waterfowl, and other small mammals.

In Minnesota these large impoundments are largely found in the Red River Basin to reduce flooding in the Red River Valley. For example, several impoundments have been incorporated in the Bois de Sioux Watershed including the North Ottawa Project and the Redpath Project. The North Ottawa Project controls 75 square miles of the Rabbit River Watershed by storing runoff in an impoundment consisting of 1,920 acres. This impoundment provides 16,000 acre-feet of storage and can reduce downstream peak flow rates by nearly five percent. This project provides flooding relief to the Wahpeton/Breckinridge area as well as thousands of acres of agricultural land.

The Redpath Project is an impoundment located adjacent to the channelized Mustinka River and will serve as an off channel storage basin. This impoundment consists of 2,100 acres of land, nine miles of dikes, and will provide 16,000 acre-feet of storage. The primary goal of this impoundment is to reduce flood damages to agricultural lands, roads, bridges, as well reduce peak flows to the receiving waters. Completion is scheduled by 2018.

Large scale impoundments are very favorable for areas that receive consistent large scale flood damage. They provide flooding relief to thousands of landowners while improving water quality through sedimentation, nutrient uptake, and reduced peak flow rates. Although these impoundments take a considerable land area and may take a significant area of agricultural land out of production, they allow for thousands of acres of previously frequently flooded agricultural land to be farmed on a consistent basis without drowning out the crops. For more information on large impoundments see http://www.frontiernet.net/~bdswd/index.htm.

Source: Red Lake Watershed District

Ditch Impoundment - Red Lake Watershed

REFERENCES

Baker JM, Griffis TJ, Ochsner TE. 2012. Coupling landscape water storage and supplemental irrigation to increase productivity and improve environmental stewardship in the U.S. Midwest. Water Resources Research, VOL. 48, W05301, doi:10.1029/2011WR011780

Lorenz DL, Sanocki C.A, and Kocian MJ, 2010, Techniques for estimating the magnitude and frequency of peak flows on small streams in Minnesota based on data through water year 2005: U.S. Geological Survey Scientific Investigations Report 2009–5250, 54 p.

Chapter Six

Ditch Channel Practices: Water Detention and Retention

6.1 IN-DITCH RETENTION STRUCTURES

NRCS Practice Standard 587, Structure for Water Control

According to Practice Standard 587, water control structures convey water, control flow direction and rate, or maintain a desired water elevation. They include a variety of weirs, dams, drop inlets, stop log weirs, culverts, or baffles.

WHERE

For water storage in ditch systems they should be placed at locations and elevations where water storage will not impede agricultural drainage or create unstable banks. They are not recommended in natural streams where fish migration and habitat might be affected.

EFFECTS

- Reduced peak flows
- Reduced sediment and nutrient delivery

These structures can be installed throughout a watershed wherever rate control or reduction is desired. Examples include: at the outlet of a wetland basin, at a branch or lateral inlet to the ditch mainline, and at the overall outlet of a drainage system. A structure for water control can be used in a drainage ditch system to provide in-channel storage and treatment. Where a section of open ditch has steeper channel slope, a structure can be installed to create a long linear pond by using the existing drainage ditch. This allows the water extra detention time to reduce downstream peak flows, thus removing sediment and nutrients from the water, while providing adequate drainage to the drainage system. Where the ditch side slope is steep or soils are less stable, it may be necessary to reduce the slope prior to installing a retention or detention structure. In addition to water quality benefits, structures for water control also provide increased wildlife habitat for fish, waterfowl, and other mammals.

COST

$15,000 *to* **$20,000** for a rate control weir, pipe through berm outlet, or similar structure for a basin with storage between 5 and 50 acre feet

Source: ISG

Low flow in the Ditch 57 Rate Control Weir - Blue Earth County, MN

Source: ISG

High flow in the Ditch 57 Rate Control Weir - Blue Earth County, MN

6.2 TWO-STAGE DITCH

A two-stage ditch is a low-flow channel inside a high-flow channel. The inner (or low flow) channel is smaller and designed to carry water during perennial flows or low flows. The benches of the larger high-flow channel act as the floodplain to the inner channel. The benches have the capacity for the high flow events while also providing an area for sedimentation, nutrient trapping, and biological treatment to occur. In natural stream classification terms, it changes the ditch from an entrenched stream to one with an accessible floodplain (Part 1).

EFFECTS

- Reduced sediment from ditch side-slope sloughing
- Reduced peak flows when coupled with down-sized culverts or weirs to detain water

Two-stage ditches are designed to mimic the hydrology of a natural stream and are primarily applicable where the majority of the flow is perennial low flows and where the existing side slopes are unstable. At low flow, the inner channel confines water away from the primary channel bank, increasing side slope stability. The inner channel also requires less cleanout maintenance compared to the standard flat ditch bottom channel, since it maintains a higher water velocity, reducing sediment deposition. For design details, see the NRCS National Engineering Handbook, Part 654, Chapter 10.

If there is enough space, two stage ditches can be constructed with a meandering low-flow channel within the larger channel, increasing time and interaction for biological processing to improve water quality. Meandering low flow channels often develop within traditional trapezoidal ditches as sediment is deposited.

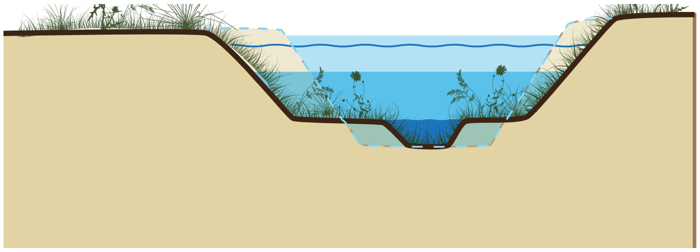
Two-stage ditches can be installed to modify an existing drainage ditch that has sloughing and erosion problems. They are often installed where a ditch improvement requires a larger pipe, therefore making an open ditch a more cost effective solution. While the two-stage ditch will provide water quality benefits wherever they are installed or constructed, optimum designs of a two-stage ditch include areas where there is a moderately rolling landscape, thus creating a steeper channel slope and higher velocities in the inner channel to create a self-cleaning system.

The cross section of a two-stage ditch is typically larger than a standard trapezoidal ditch, which combined with restricted size culvert outlets, allows more water storage for peak flow reduction.

COST

$75 *to* **$100** per linear foot for new construction

$25 *to* **$40** per linear foot for channel modification



Source: Bruce Wilson

Cross section of a two-stage ditch (green) superimposed on a standard trapezoidal ditch (blue). Because the wider two-stage ditch has less water depth at high flows it has less shear force on the channel bottoms and sides. At low flow, water is confined away from the primary channel bank, increasing side slope stability.

Source: ISG

Example of a two-stage ditch: Ditch 57 - Blue Earth County, MN

Source: Jon Lore, MN DNR

Standard drainage ditch with natural low-flow meander.

REFERENCES

USDA-NRCS National Engineering Handbook, Part 654 Stream Restoration Design, Chapter 10: Two-stage channel design. http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17770.wba

ADDITIONAL READING

http://greatlakeswater.uwex.edu/two-stage-ditch-design-concept (Resources tab)

Two-stage ditches, a webpage at Purdue University: https://engineering.purdue.edu/watersheds/conservationdrainage/ditch.html

Krider L, Kramer G, Hansen B, Magner J, Lahti L, DeZiel B, Zhang L, Peterson J, Wilson B, Lazarus B, Nieber J. 2014. Cedar River alternative ditch designs. Final Report to EPA-319. https://wiki.umn.edu/pub/Wilson/DownloadReports/AlternativeDitchDesign_EPA319_FinalReport.pdf

Chapter Seven

Riparian Practices: Restoration and Protection

The emphasis of this document is primarily on practices for moderating the flows from uplands that cause excessive streambank, bluff, and ravine erosion. While not the focus of this book, a very brief introduction to types of practices employed for direct stream restoration and bank protection is provided here. References in this chapter and supplemental reading suggestions at the end provide extensive and detailed guidance on stream corridor protection and restoration.

7.1 RIPARIAN VEGETATION

Riparian vegetation is a mix of grasses, forbs, sedges, and sometimes trees that serves as an intermediate zone between upland and aquatic environments. Deep-rooted species in particular help to stabilize banks by anchoring soil and removing water that causes loss of soil cohesion and gravity-driven bank collapse. Native species are preferred for their stability and rooting depth.

EFFECTS

- Improved streambank and ditch stability
- Reduced nutrient and sediment delivery
- Reduced stream velocity
- Enhanced nutrient removal

Riparian vegetation provides enhanced water quality benefits through sedimentation, uptake in nutrients, and energy dissipation of high streamflows while providing additional habitat for aquatic species. Typically, riparian vegetation is installed in or along streambanks where during high flow periods, surface water makes contact with the vegetation, providing benefits to surface water quality and aquatic species. It is also installed between upland vegetation such as filter strips and buffers, and the stream channel to act as an additional filter of surface runoff.

COST

$125 *to* **$175** per linear foot

Source: The Nature Conservancy

Big Woods Stream Restoration

7.2 STREAMBANK AND SHORELINE PROTECTION

NRCS Practice Standard 580, streambank and shoreline protection

Streambank and shoreline protection practices are used where high rates of bank and bluff erosion are undermining infrastructure or causing excessive loss of land near farms or homes. Traditionally hard-armoring approaches were used such as rip-rap. Now bioengineering using native plant materials combined with limited use of rock and/or logs is often favored over armoring approaches because of the habitat, aesthetic and cost benefits provided by using natural materials. Both hard armoring and bioengineering approaches require design and implementation by skilled practitioners to avoid expensive and environmentally damaging failures.

EFFECTS

- Reduced streambank and bluff erosion and collapse at the protected site
- Reduced loss of farmland and threatened structures
- Increased native grasses and shrubs in riparian corridor
- Aesthetic potential

There are too many streambank and shoreline protection practices, both structural and bioengineering based, to describe in this document. See the NRCS Field Office Technical Guide, and the National Engineering Handbook (NEH) Part 650, Engineering Field Handbook Chapter 16, Streambank and Shoreline Protection, for a wide range of these practices. Engineering guidance is also given in:

- NRCS NEH Part 653, Stream Corridor Restoration: Principles, Processes, and Practices
- NRCS NEH Part 654, Stream Restoration Design

See the Minnesota Soil Bioengineering Handbook (Minnesota Department of Transportation, 2005) for planting recommendations and project examples specific to Minnesota and the upper Midwest.

For photos of examples of bioengineering with vegetation/ engineering hybrid designs, see Nelson and Melchior, 2012.

COST

$500 *to* **$1,000** per linear foot for bioengineering practices, if major modification is required.

Source: ISG

Stream restoration with boulders, willows and native plantings, Chankaska Creek - Kasota, MN

Source: Goodhue Soil and Water Conservation District, Minnesota

Streambank protection with the bioengineering practices of cedar revetments installed with duckbill anchors and braided cable on Prairie Creek (top photo) and root wad/toe wood installation on the Cannon River (bottom left). The hybrid engineering/bioengineering practice of rip rap combined with root wads is on Hay Creek (bottom right.)

7.3 RESTORE CHANNEL MEANDERS

Straightened channels can be re-directed into previously abandoned meandering channels or can be partially connected to floodplains at high flows (Lenhart et al. 2010). Where the original stream is no longer present, a new stream channel can be constructed.

EFFECTS

- Reduced stream velocity resulting in reduced streambank erosion
- Increased in-channel storage
- Improved aquatic habitat

Re-meandering increases the overall channel length which reduces the channel slope, decreasing shear forces and sediment transport capacity. Meanders increase travel time, reducing flood peaks downstream. Re-meandering improves habitat for fish and invertebrates by re-establishing a variety of water depths and velocity. Restoring meanders and their associated habitat, such as riffles, runs and pools, results in a dramatic increase in available fish habitat. If designed properly, these streams will transport sediment efficiently and will have little or no impact on flooding. Like streambank protection, restoring meanders is usually an engineering project requiring design and implementation by skilled practitioners.

Source: USDA-FSA Aerial Imagery 2013

The Whitewater River was diverted back into its original meandering channel and the previously straightened and enlarged channel has been blocked in several locations.

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Lenhart C, Brooks K, Magner J, Suppes B. 2010. Riparian corridor-channel restoration and management in Elm Creek, Minnesota. Ecological Restoration 28(3): 240-242.

Minnesota Department of Transportation (MNDOT) 2005. Minnesota Soil Bioengineering Handbook.

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NRCS Field Office Technical Guide, http://efotg.sc.egov.usda.gov

NRCS National Engineering Handbook Part 650, Engineering Field Handbook Chapter 16, Streambank and Shoreline Protection. http://directives.sc.egov.usda.gov/Default.aspx

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SUPPLEMENTAL READING

Sanders RE. 2000. A guide to Ohio Streams. Ohio Chapter of the American Fisheries Society

The Izaak Walton League of America. 2006. A handbook for stream enhancement & stewardship. The Izaak Walton League of America.

Williams JE, Dombeck MP, Wood CA. 2012. My healthy stream: a handbook for streamside owners. Trout Unlimited and The Aldo Leopold Foundation.

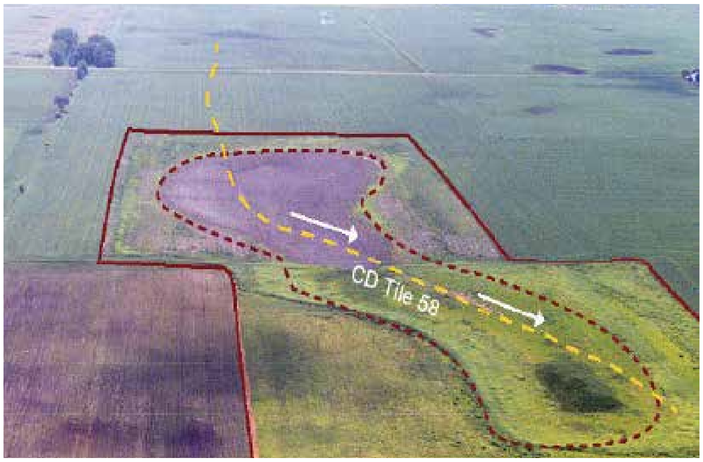
Chapter Eight

Watershed Planning and Management

Fields and farms are connected by ditches and streams throughout a watershed, with downstream consequences of upstream actions. Watershed-scale planning and management are needed to find effective and cost-efficient solutions to stream-related problems. A watershed approach considers three aspects:

- The geography of the problem: How does an issue at one site relate to upstream and downstream issues?
- The geography of the solutions: Look across an entire watershed (instead of a single parcel) to identify likely contributing areas as well as opportunities for water storage and other practices in order to maximize return on conservation investment.
- Multipurpose management: How can we simultaneously address multiple goals including water quality improvements, flood mitigation, and agricultural production?

A wetland was created in the Seven Mile Creek watershed, Nicollet County, Minnesota, by daylighting tile into a field that had been difficult to drain. Now, upstream neighbors have a more effective outlet for their drainage systems, downstream neighbors are flooded less often, and nitrate levels in the drainage systems are reduced.



Source: Kuehner, K. 2009 - Seven Mile Creek Watershed Project

8.1 THE IMPORTANCE OF MANAGING ACROSS A WATERSHED

As described in the watershed chapter, land and water are tightly connected. The sum of land management across a watershed is reflected in flow rates, water quality, channel shape, and other characteristics of streams.

Most properties receive water from neighboring properties and send water to other neighbors. The quantity and quality of the water depends in part on how the land uphill is managed. Treating a problem at one downstream site does not solve the upstream cause. For example, a landowner might install rip-rap on the newly eroding bank of a stream, but the increased flows that may have caused the problem will continue to erode other stream segments.

CRITICAL SOURCE AREAS VARY ACROSS THE WATERSHED

Not all sites contribute equally to water characteristics. Because of their shape, soil, and land cover, some locations are particularly significant sources of pollutants or high water flows. Identifying these critical source areas is important for directing resources effectively.

OPPORTUNITIES VARY ACROSS THE WATERSHED

Just as some sites are critical source areas, some sites are more suited to particular management practices. Landscape position guides opportunities. For example, depressions are suited for restored or constructed wetlands, concentrated flow paths are suited for waterways and WASCOBs, and the toe of a slope is suited for grass infiltration strips.

DRAINAGE-SHEDS

Like watersheds, drainage systems are best managed as whole systems, and integrated with planning for the larger watershed. Commonly, segments of a drainage system are improved or repaired only when landowners petition the drainage authority. Local improvements or repairs can last longer and be more cost effective when they are part of a system-wide consideration. For example, storage in the middle of a drainage system can reduce the size of pipe and ditches required downstream, and reduce frequency of downstream flooding in the system.

MULTIPLE MANAGEMENT GOALS

When addressing a water problem, different stakeholders will have different top priorities, such as maximizing agricultural production, protecting public or private infrastructure, preserving wildlife habitat, or providing clean water. A watershed perspective is often needed to identify solutions that address all of these concerns.

BENEFITS

Watershed scale planning ensures that financial resources are used efficiently and cost-effectively to address water management issues. Planning allows private and public managers to:

- Acknowledge and address diverse water management goals
- Site water storage opportunities to minimize loss of productive land
- Maintain or increase drainage outlets and drainage capacity
- Reduce long term maintenance costs for drainage systems
- Reduce flood damage
- Identify critical soil loss sites
- Build partnerships needed for projects that cross property boundaries such as large wetland restorations, or terraces with an outlet tile crossing boundaries

COST

$10,000 *to* **$25,000** for multipurpose drainage plan for 1,000 to 10,000 acres

Source: David Mulla, University of Minnesota

Paths of concentrated flow in fields bordering a ditch

The location of gullies or washouts can be predicted by calculating the Stream Power Index from LiDAR elevation data. Desktop analysis like this provides information that can streamline field work. Green dots are field-verified gullies entering the ditch.

Source: ISG

Multipurpose drainage plan for Ditch 2 M&W Watershed in Martin County. Some drainage authorities such as Martin County have assessed needs and opportunities across a drainage system. This plan will help them respond more cost effectively to petitions for repairs or improvements.

http://www.co.martin.mn.us/images/Ditch%20Admin/Martin%20County%20Multipurpose%20Drainage%20Management%20Plan.pdf

8.2 LOCATING STORAGE IN A WATERSHED

Installing water storage can benefit many people in a watershed, but selecting a site for storage takes more than a willing landowner. The site must have a shape and elevation that allows for adequate storage, and it needs to be at an effective point along the path of water.

Retention, such as reducing culvert size, generally needs to be applied in upper reaches before being applied in lower reaches of a stream. If lower reaches are retained first, two problems can occur after a large storm:

- Un-retained water from the upper reaches will overwhelm the lower, reduced-sized culverts, potentially washing out roads.
- Un-retained water from the upper watershed and retained water from the lower watershed may reach the mainstem at the same time instead of being spread out in time. The result would be a higher flood peak near the mouth of the watershed.

8.3 WATER RESOURCE AUTHORITIES

Water resource management is governed by multiple federal, state, and local agencies and their laws and rules. Many entities are interested because water management impacts public health, land rights, property value, and economic activities including agriculture, recreation, navigation, energy production, manufacture, and other industries.

Maintenance of public drainageways is regulated by Minnesota statue section 103E

https://www.revisor.mn.gov/statutes/?id=103E Application of the statute is explained in the Minnesota Public Drainage Manual (available at http://www.bwsr.state.mn.us/drainage/)

The authority of WDs and WMOs is defined in Minnesota statute section 103D https://www.revisor.mn.gov/statutes/?is=103d

For most individuals, the best access point to water-related authorities in Minnesota is local government agencies including Soil and Water Conservation Districts (SWCDs), Watershed Districts (WDs), Drainage Authorities, cities, and counties. These entities understand the local issues and stakeholders, can access state and federal resources, know the legal requirements, and have gone through planning processes to identify water resource priorities and opportunities. WDs, SWCDs, and Drainage Authorities complement one another because they have different types of funding sources, different expertise, and different authority. “One Watershed, One Plan” is a newly established state policy that allows counties, WDs and SWCDs to collaborate to create a single planning document for a watershed that may cross county boundaries.

SOIL AND WATER CONSERVATION DISTRICTS (SWCDs) generally follow county boundaries, have an elected board, and often get base-funding from the associated county. They have relationships with many landowners and technical expertise with conservation practices.

WATERSHED DISTRICTS (WDs) AND WATERSHED MANAGEMENT ORGANIZATIONS (WMOs) follow watershed boundaries, are led by county-appointed boards, and have authority to raise funds through levies, make rules, and require permits. They are especially well-positioned to do watershed-based planning and implementation because they follow watershed boundaries. WDs are only organized in some parts of Minnesota. In remaining parts of the state, water resource management is primarily led by counties and SWCDs. A map of watershed districts is available from the Minnesota Association of Watershed Districts http://www.mnwatershed.org/ .

DRAINAGE AUTHORITIES may be either the County Board or the Watershed District Board. They are responsible for managing public drainage systems in response to owner petitions for improvements or repairs. “Public drainage systems” are owned by the landowners who benefit from the system, not the Drainage Authority. Improvements and repairs are funded by assessments to the benefiting landowners, not by general funds. The Drainage Authority may choose to systematically redetermine who the beneficiaries of a system are and thus who is assessed for repairs. (Often, the beneficiaries were defined decades ago when the system was first established.) County-wide redetermination may be an important component of watershed-scale planning. In addition to redetermination of benefits, Drainage Authorities can assist water resource management by identifying opportunities for flow mitigation.

OTHER LOCAL ORGANIZATIONS include watershed projects, joint powers agreements, and citizens' associations. Joint Powers Organizations are created by multiple counties or other government entities. Lake or river associations are non-governmental organizations that generally work closely with governments. These organizations may have no formal authority, but are important for coordinating activities and bringing stakeholders together. Some examples are the Crow River Organization of Water (CROW), Hawk Creek Watershed Project, Whitewater River Watershed Project, Chippewa River Watershed Project, Pomme de Terre River Association, and Pine River Watershed Alliance.

8.4 EXAMPLES OF WATERSHED MANAGEMENT

To initiate watershed management, or a multi-landowner project, some of the first steps are:

- Contact the SWCD, WD, or county Environmental Services Department to learn about legal requirements, funding, and technical support
- Learn the local hydrology and learn who is impacted
- Examine existing county or watershed plans for information about the local hydrology, priorities, and opportunities.
- Discuss needs and opportunities with impacted landowners
- Use existing desktop tools, such Geographic Information System (GIS) software, to identify critical source areas, locate opportunities for installing practices, and do initial design and cost estimates

In relation to agricultural drainage, there are many ways to approach watershed planning, including county-wide redetermination of drainage benefits, adopting rules for drainage installation and other water-related activities, drainage and culvert records modernization, and county-based drainage-shed planning. The following are just a few examples.

MARTIN COUNTY MULTIPURPOSE DRAINAGE MANAGEMENT PLAN

- http://www.co.martin.mn.us/images/Ditch%20Admin/Martin%20County%20Multipurpose%20Drainage%20Management%20Plan.pdf
- Project site: http://www.co.martin.mn.us/index.php/government/ditch-administration

FARIBAULT COUNTY

- Drainage Records Modernization http://www.legacy.leg.mn/projects/creating-web-based-drainage-management-tool-faribault-county-0
- Multipurpose drainage planning http://www.legacy.leg.mn/projects/drainage-management-planning-faribault-countys-future

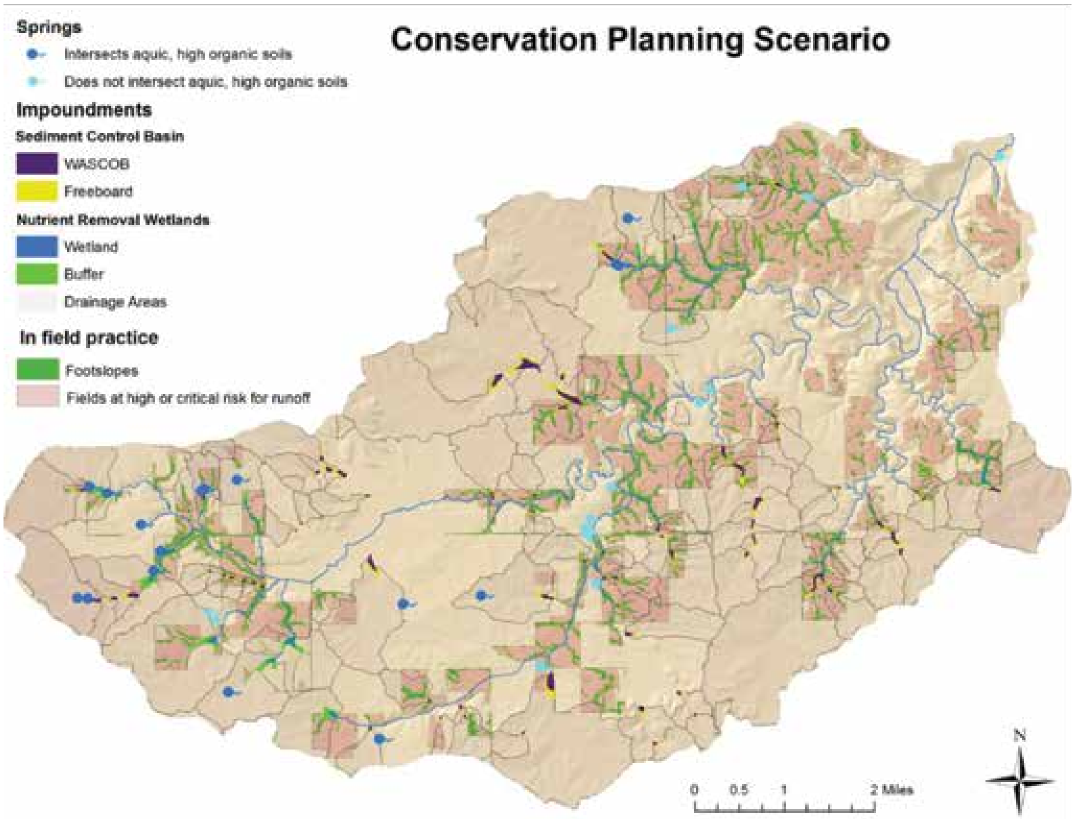
BOIS DE SIOUX WATERSHED DISTRICT

- http://www.bdswd.com/
- The primary concern of the BDSWD is flood mitigation rather than water quality.
- See Tile Pump Status page for example of how the district manages water.

- See "Projects" page for information about the 1,920-acre North Ottawa water impoundment project and their Ditch Records Modernization effort.
- Their 2010 Annual Report describes their permitting rules. "Permits are required for any type of work related to new ditching, improved ditching, drainage from one sub-watershed to the other, construction, alteration or removal of any dike, reservoir work, land forming, wetland drainage, work within natural drainage ways, lakes, wetlands and other abutting land and drainage structures."

POTENTIAL SCENERIOS FOR WATERSHED TREATMENT

A desktop analysis generated this map of possible sites for various conservation practices and sites with high runoff risk within a small watershed. Developed using the Agricultural Conservation Planning Tool.



Source: Mark Tomer, USDA-ARS - Ames, IA

REFERENCES

Kuehner, K. 2009. Seven Mile Creek Watershed Project. Final report to the Minnesota Pollution Control Agency, Phase II, Clean Water Partnership. Brown Nicollet Cottonwood Water Quality Joint Powers Board.

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EXTENSION