Conservation Drainage – Emerging Issues and Recent Developments

2012 BWSR Academy

October 29, 2012

Cragun's Conference Center

Al Kean, PE

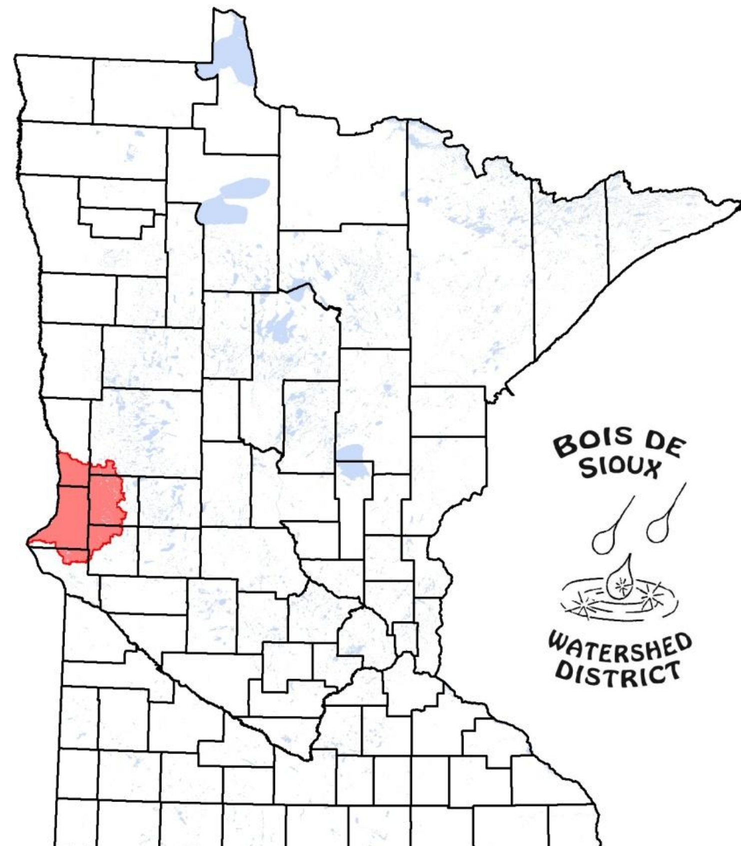
Chief Engineer, BWSR

Drainage – Issues and Developments During 2012

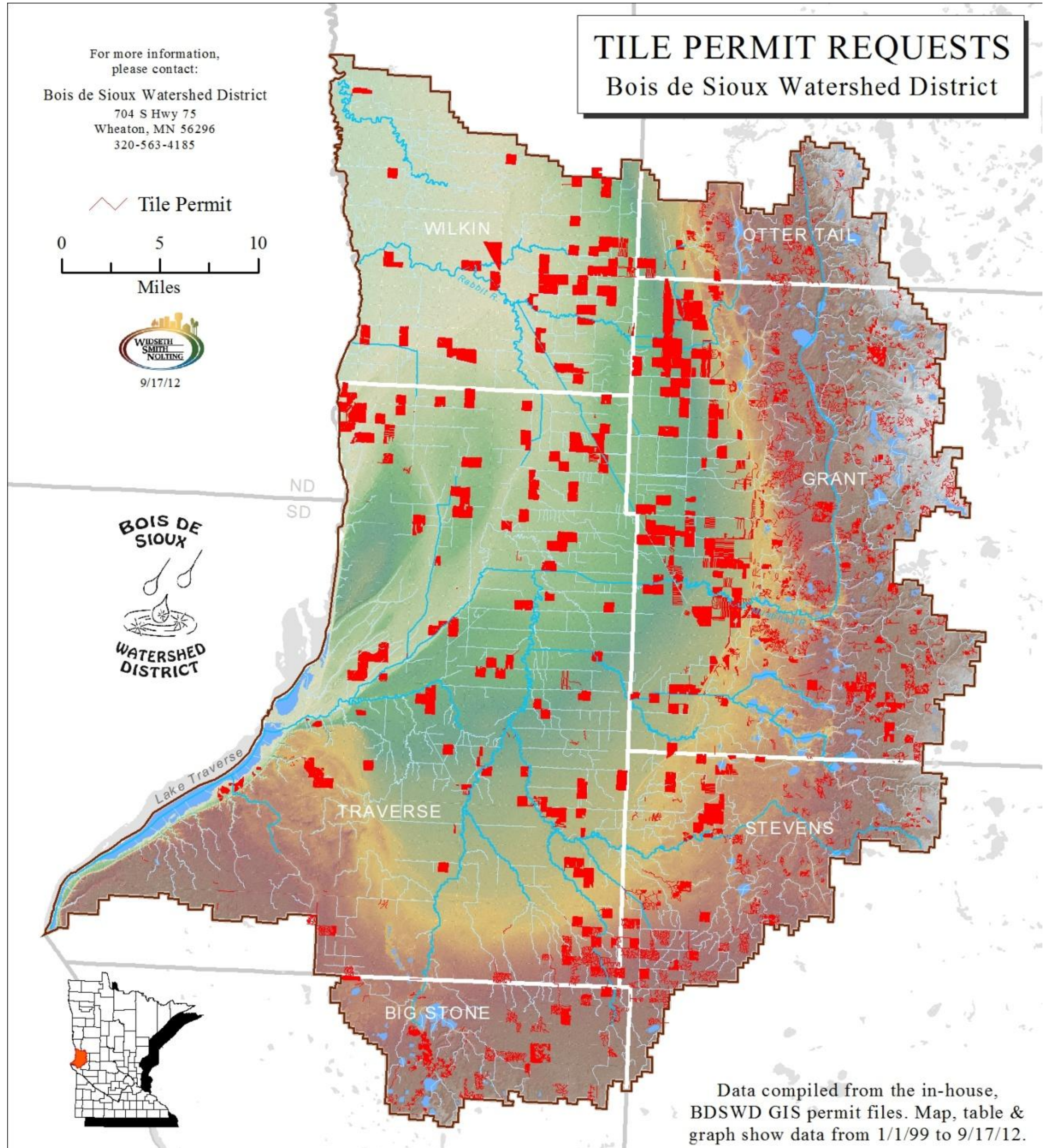
- Tiling continues at a rapid pace
- Evolving drainage related practice categories and terms
- Red River Basin – Effects of tile drainage on flood peaks and management options (BTSAC)
- "Intensified Tile Drainage Evaluation" report by Science Museum of Minnesota, St. Croix Research Station
- NRCS Drainage Water Management (DWM) initiative
- BWSR Drainage Water Management (DWM) initiative
- Saturated Buffer – New Conservation Drainage practice

Red River Basin and Bois de Sioux Watershed District Boundaries

The Red River of the North is an international watershed.



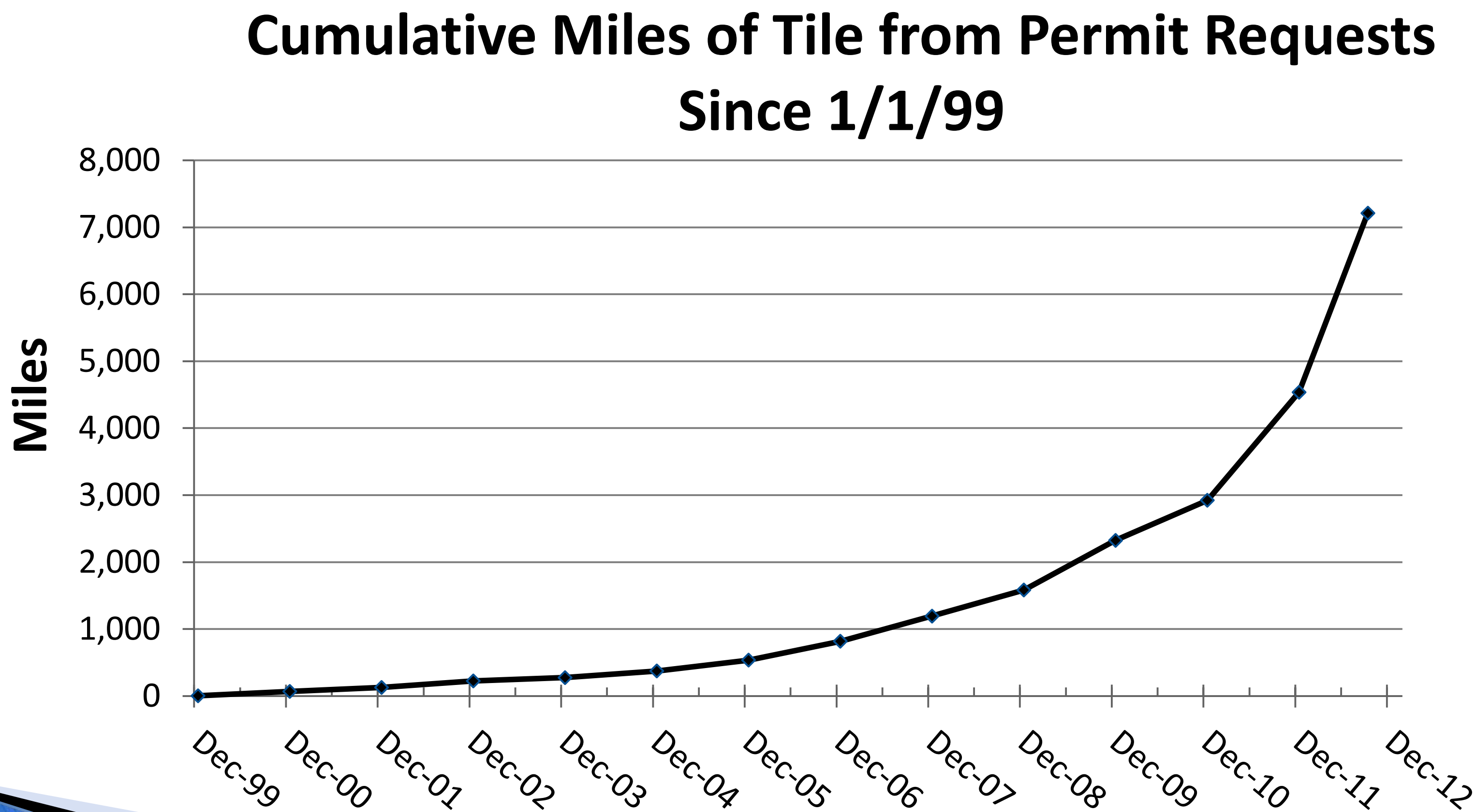
Ag Tile Drainage Permits 1/1/99 - 9/17/12 Bois de Sioux Watershed District



Miles of Ag Drainage Tile Permitted

1/1/99 - 9/17/12

Bois de Sioux Watershed District



Source: Bois de Sioux WD and WSN, Inc.

Minnesota Board of Water & Soil Resources

Ag Drainage Tile Permitted 1/1/99 - 9/17/12 Bois de Sioux Watershed District

Year	Miles
Dec-99	2.9
Dec-00	65.3
Dec-01	59.4
Dec-02	97.4
Dec-03	49.2
Dec-04	100.0
Dec-05	162.1
Dec-06	281.5
Dec-07	374.7
Dec-08	390.6
Dec-09	740.9
Dec-10	599.3
Dec-11	**1612.9**
Sep-12	**2675.2**
Total	**7211.5**

Source: Bois de Sioux WD and WSN, Inc.

Minnesota Board of Water & Soil Resources

Multipurpose Drainage Management

MULTIPURPOSE GOALS

- **Provide adequate drainage for crop production.**
- **Reduce runoff**, flow concentration, peak flows, and flood damage.
- **Reduce erosion of agricultural lands** to improve sustainability.
- **Improve water quality** by reducing field, ditch and stream erosion, as well as pollutant concentration and carrying capacity.
- **Improve wildlife habitat**.
- **Target investments** where drainage management has the most effect.

CATEGORIES OF CONSERVATION PRACTICES
(Evolving Terminology)

- **All Cons. Practices (NRCS FOTG = 111)**
  - **- Multipurpose Drainage**
    - **- Conservation Drainage**
      - **- Drainage Water Mgmt. (DWM)**

- **On Field**
- **On Farm**
- **On Drainage System**

- **Structural**
- **Nonstructural**

Evolving Categories of Key Drainage Related Practices

Conservation Practice	Multipurpose Drainage	Conservation Drainage	DWM
Residue Management (329, 344, 345, 346)	✓		
Nutrient Mgmt. (590) & Cons. Activity Plan (CAP) 104	✓	✓	✓
Grassed Waterway (412)	✓		
Terrace (600)	✓		
Water and Sediment Control Basin (638)	✓		
Grade Stabilization Structure (410) – Side Inlet	✓	✓	
Drainage Water Management (554) & CAP 130	✓	✓	✓
Structure for Water Control (587)	✓	✓	✓
Denitrifying Bioreactor (747)	✓	✓	✓
Subsurface Drain (606) (Replace Open Inlet)	✓	✓	✓
Wetland Restoration (657); Constructed Wetland (656)	✓		
Vegetated Subsurface Drain Outlet (739) (Sat. Buffer)	✓	✓	?

Keys to Multipurpose Drainage & Conservation Implementation

- Many conservation practices support multiple goals
- Successful conservation typically requires:
  A. Good science and experience for conservation practices that work (stds. and specs, cooperator acceptance / compatibility with farming operations)
  B. Technical Assistance
  C. Financial Assistance
  D. Willing landowners / cooperators (marketing, cooperator trust)

Guiding Principles for Multipurpose Drainage Mgmt.

- Reduce runoff and N loss by increasing soil profile water storage and cover crops
- Avoid runoff concentration
- Protect concentrated flow areas from erosion
- Reduce peak flows to reduce erosion and flooding, and to improve water quality and habitat
- Manage nutrients and denitrify tile drainage
- Do all of the above to improve agriculture sustainability
- Target investments for both incremental practices and watershed approaches

Reduce Runoff and N Loss via Soil Water, ET and Cover Crops

- Conservation Tillage
  - Residue Management (Strip-Till, Ridge Till, No-till)
- Drainage Water Management (Controlled Subsurface)
- Wetland Restoration
- Soil Health / Soil Quality
  - For some typical MN soils: 1% increase in soil organic matter (SOM) in the top 30 inches of soil = approximately ¾ in. to 1 in. increase in water holding capacity, or 7 - 14 days plant available water increase
- Cover Crops
  - More feasible due to tile drainage, shorter growing season corn hybrids, new cover crops, and experience

Avoid Runoff Concentration

- Conservation Tillage
  - Residue Management (Strip-Till, Ridge Till, No-till)
- Contour Farming, Strip Cropping, Buffers
- Cover Crops
  - More feasible due to tile drainage, shorter growing season corn hybrids, new cover crops, and experience

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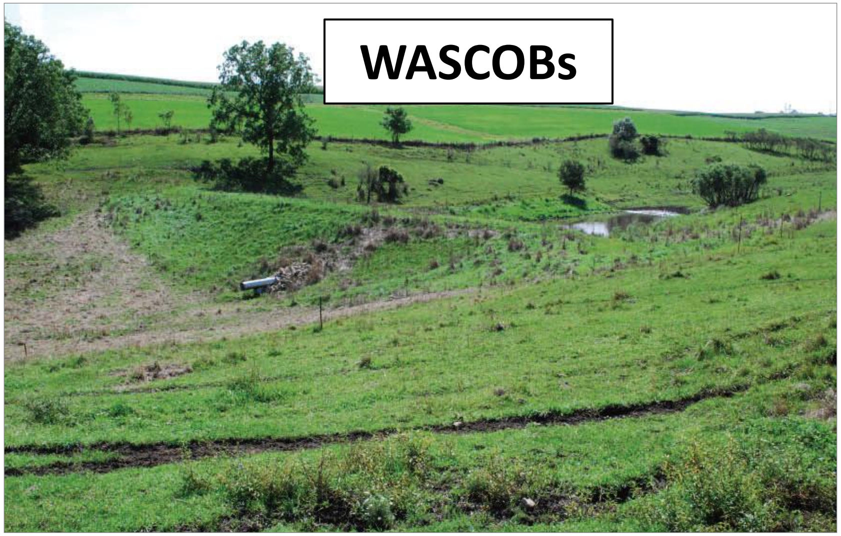
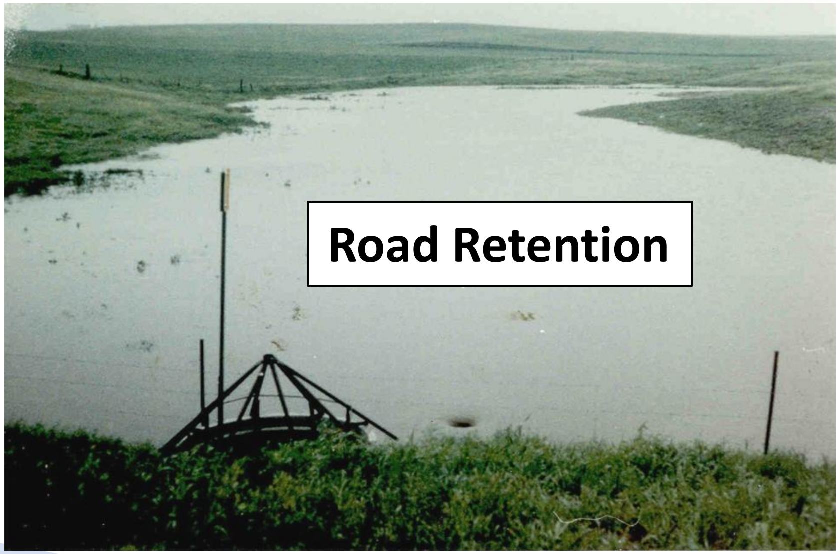
Protect Concentrated Flow Areas from Erosion

Reduce Peak Flows to Reduce Erosion and Flooding





Manage Nutrients and Denitrify Tile Drainage

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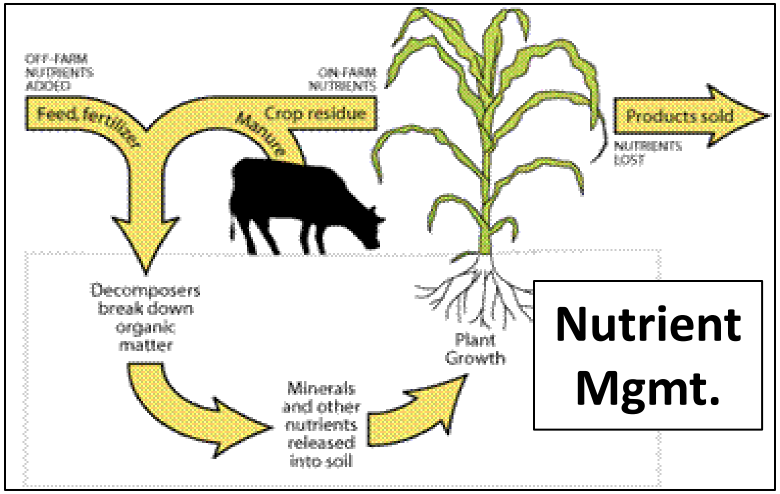
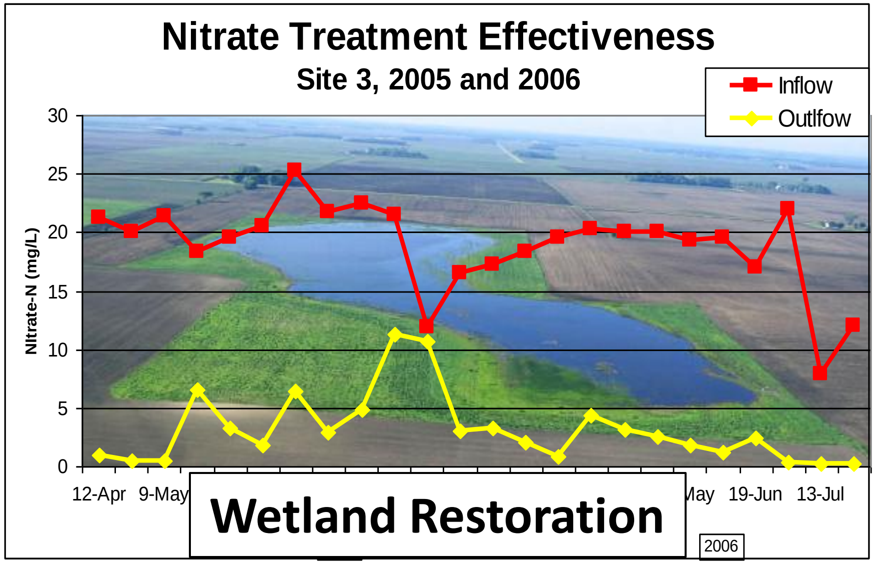
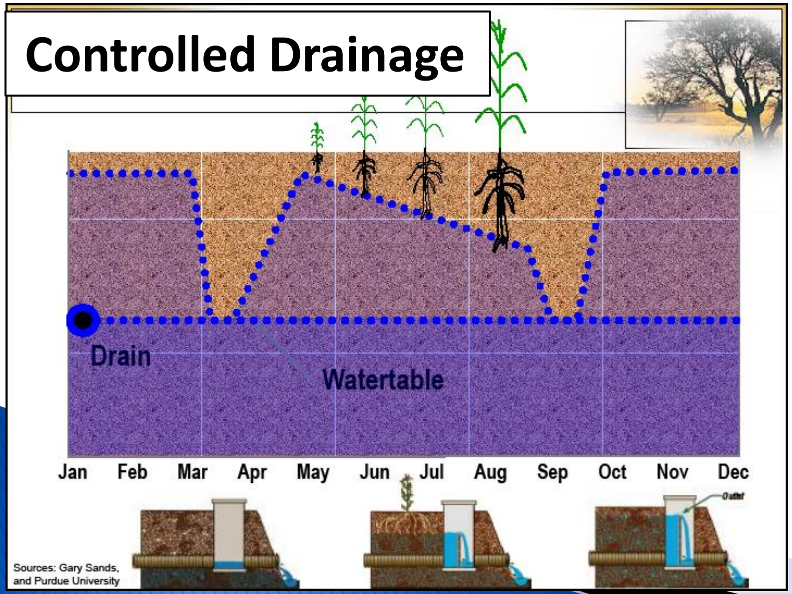
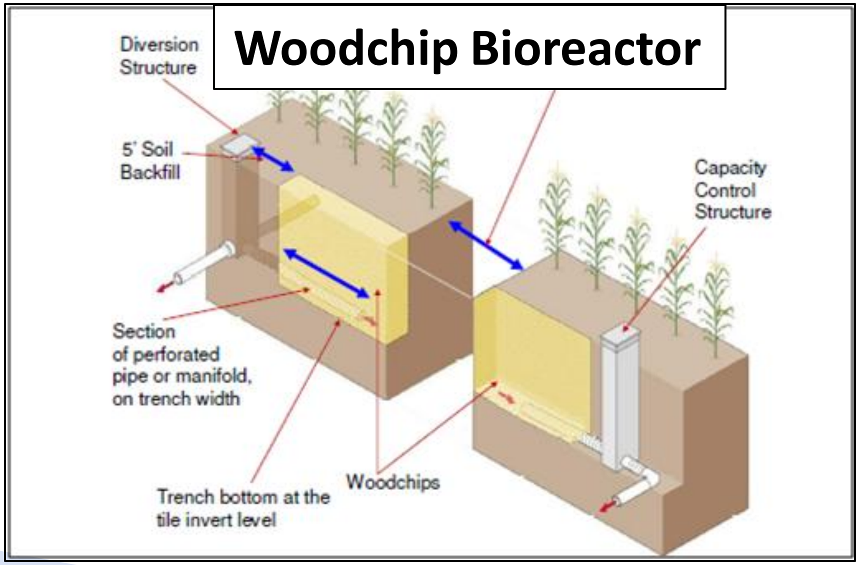








Red River Basin – Study of Drainage Effects on Flood Peaks

- 2009 Red River of the North Flood
- ND Red River Joint Water Resources District and MN Red River Watershed Management Board form interstate joint powers board
- Red River Retention Authority Joint Drainage Committee asked:
  - *What are the impacts of agricultural drainage on peak basin flows?*
  - *How should agricultural drainage systems be designed to maximize benefits while minimizing adverse impacts?*
- Red River Retention Authority asked the International Water Institute to establish an objective process to address questions
- **Basin Technical and Scientific Advisory Committee (BTSAC)**

Basin Technical and Scientific Advisory Committee (BTSAC)

Stakeholder	Representative	Stakeholder	Representative
MN Red River Watershed Management Board	Charlie Anderson	ND Red River Joint Water Resources Board	Kurt Lynse
City of Fargo, ND	Mark Bittner	US Geological Survey	Rochelle Nustad
MN Red River Watershed Management Board	Nate Dalager	ND Natural Resources Conservation Service	Dennis Reep
US Fish and Wildlife Service	Josh Eash	ND State Water Commission	Bill Schuh
International Water Institute	Charles Fritz	MN Department of Agriculture	Rob Sip
ND Red River Joint Water Resources Board	Randy Gjestvang	MN Department of Natural Resources	Jim Solstad
MN Natural Resources Conservation Service	Dave Jones	MN Red River Watershed Management Board	Dan Thul
US Army Corps of Engineers	Scott Jutila	MN Center for Environmental Advocacy	Henry VanOffelen
MN Board of Water and Soil Resources	Al Kean	City of Moorhead, MN	Bob Zimmerman

Hydrologic Cycle in Minnesota (Water Budget)

- UMN Technical Bulletin 322, 1979, Climate of Minnesota, Part XII, "The Hydrologic Cycle and Soil Water"
- Mass balance of water: input = Precipitation (rain & snow) 1941 - 1970 data for 15 watersheds across MN: Ave. 21 in. - 31 in. NW to SE across MN
- 3 categories of water output / recycling:
  - **Evapotranspiration (combined):** Ave. **76%**, range about 40% – 90% far NE to W
  - **Runoff:** (1960 – 1976 data) Ave. **22%**, range about 10% - 60% W to far NE
  - **Infiltration to Groundwater:** Ave. **2%**

BTSAC Briefing Paper #1
"Impacts of Subsurface Ag Drainage on Watershed Peak Flows", 3-30-11

- Extensive literature search and current research review
- Key Conclusions:
  - *<u>Most available subsurface drainage research is at the field scale</u>, with very little at the watershed scale*
  - ***Subsurface drainage reduces surface runoff and typically delays and reduces peak flows <u>at the field scale</u>***
  - ***Subsurface drainage can increase annual water yield (volume) (predominately in the spring and fall)***
  - *Any general statement implying that subsurface drainage decreases (or increases) flood peaks is strongly discouraged because it oversimplifies the complex processes involved.*

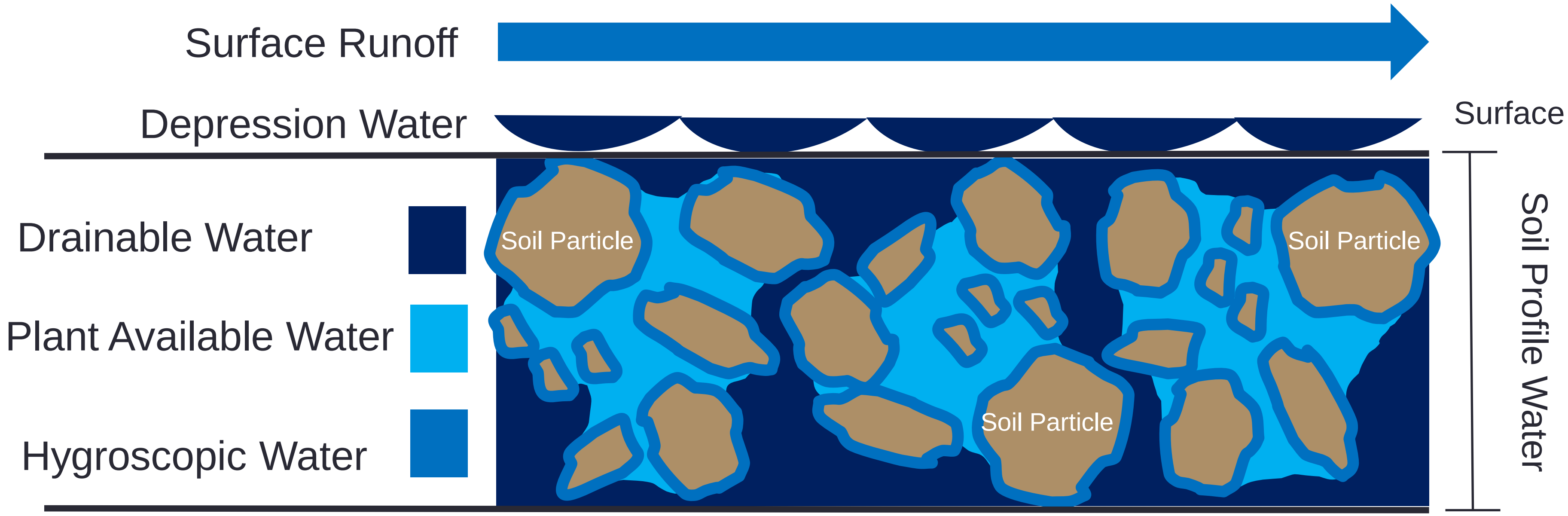
Available at:
WWW.RRBDIN.ORG

BTSAC Briefing Paper #2
"Water Management Options for Subsurface Drainage", 4-5-12

- More detailed evaluation of the effects of tile drainage on hydrology and recommendations to RRRA water managers
- Key Conclusions:
  - ***Situations exist where adding uncontrolled subsurface drainage to areas of the landscape has the potential to increase flooding. This risk must be considered and evaluated in water management decision making.***
  - ***The inclusion and appropriate operation of control structures on existing and proposed subsurface drainage systems can maximize water storage potential and reduce flood flows.***

Available at:
WWW.RRBDIN.ORG

Partitioning of Soil Profile and Surface Water



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Key Water Storage Categories

- **Retention** – Water stored for extended periods of time (**weeks or months**). For example a "wet" impoundment with a "permanent", or "normal" pool. *Long-term storage enables substantial evaporation and transpiration (volume reduction).*

- **Detention** – Water stored for a limited period of time (**hours or days**). For example a "dry" impoundment and the water that is only detained. *Short-term storage does not enable much evaporation and transpiration (volume reduction).*

Wetland - detention

Wetland - retention

Maple River Dam - detention

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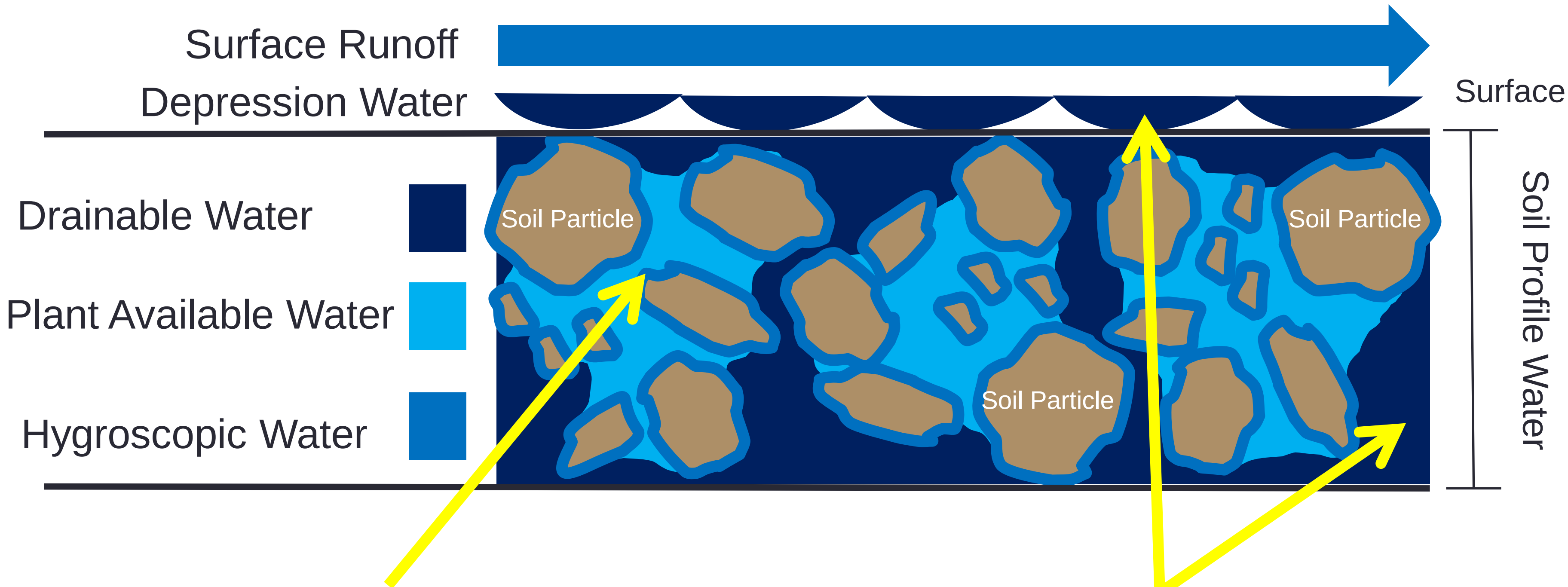
Without Subsurface Drainage



Hygroscopic and Plant Available Water =
Retention Storage

Drainable Water and Surface Depression Water =
Retention Storage

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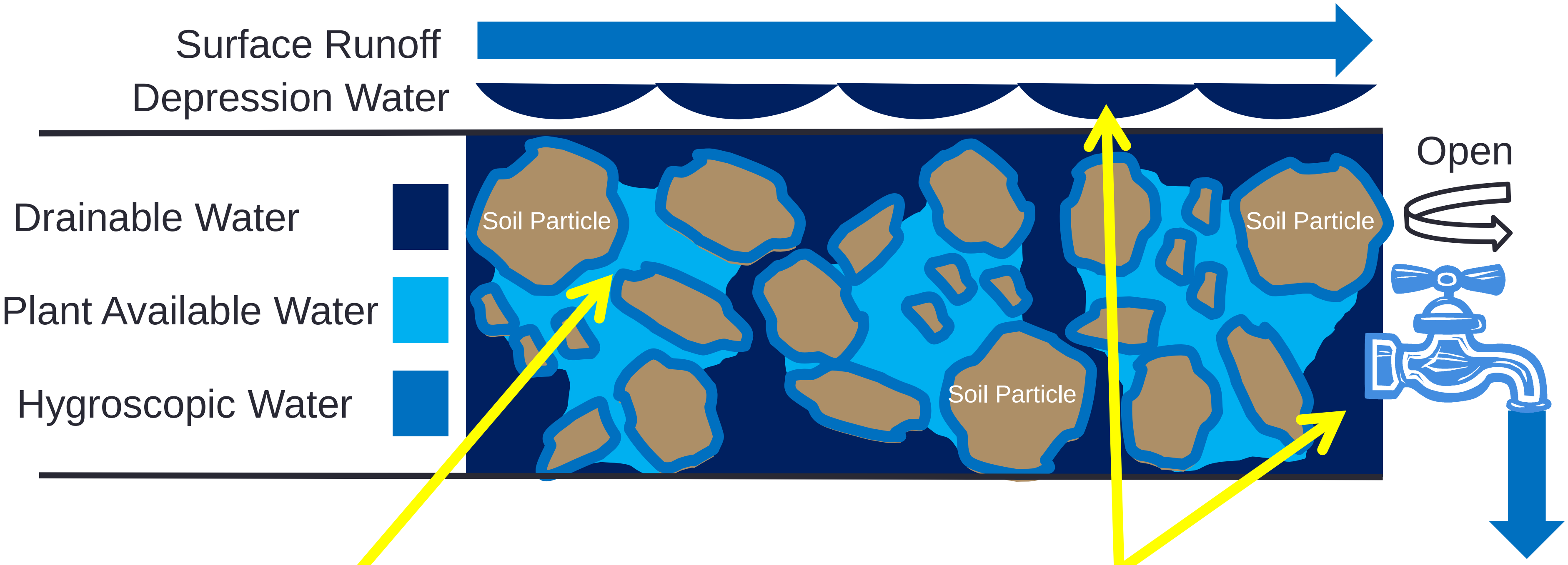
With Subsurface Drainage



Hygroscopic and Plant Available Water =

Retention Storage

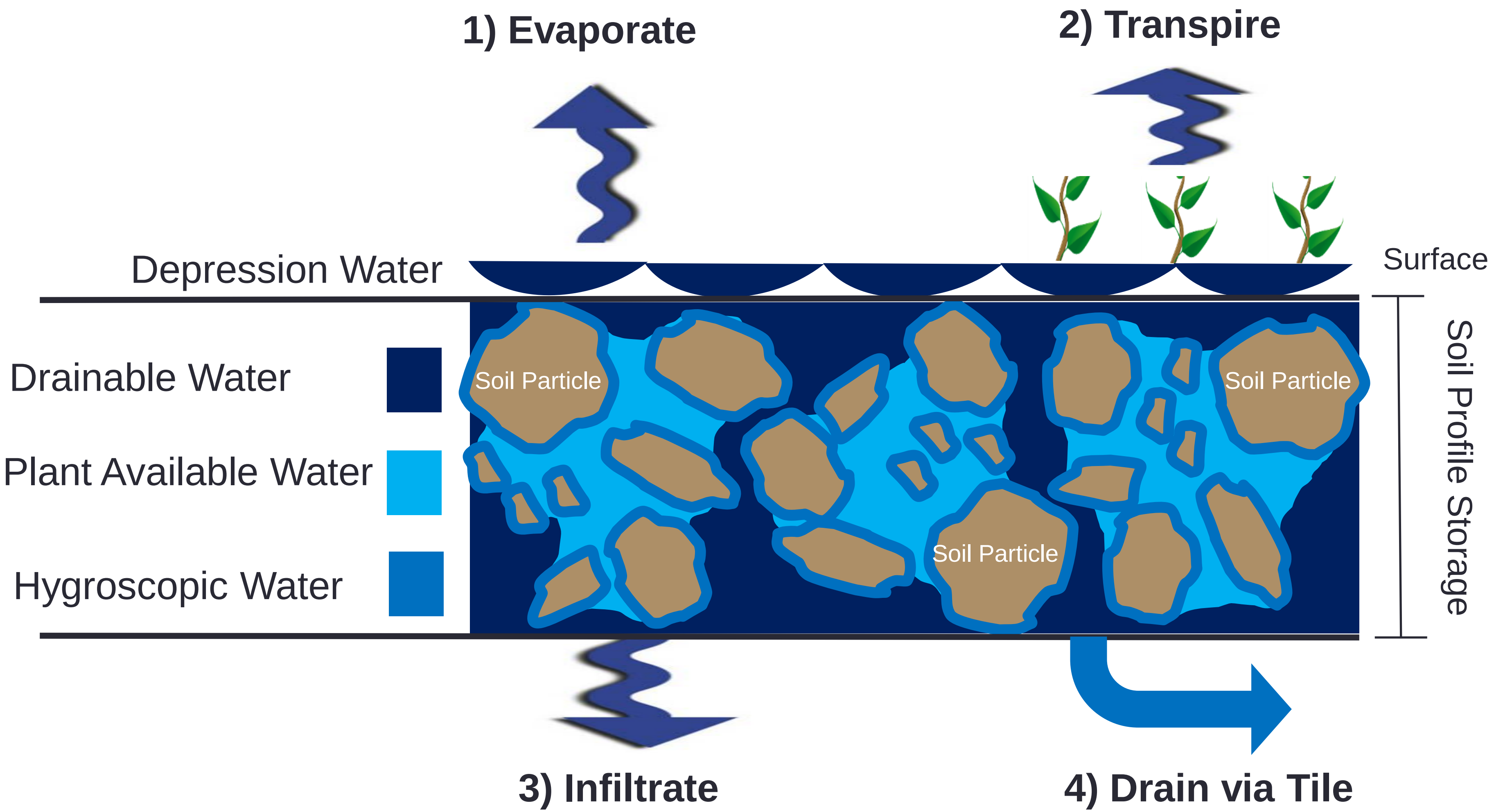
~~Drainable Water and Surface Depression Water =~~

~~***Retention Storage***~~

Drainable Water and Surface Depression Water =

<u>Detention</u> Storage

Fate of Drainable Soil Profile and Surface Depression Water



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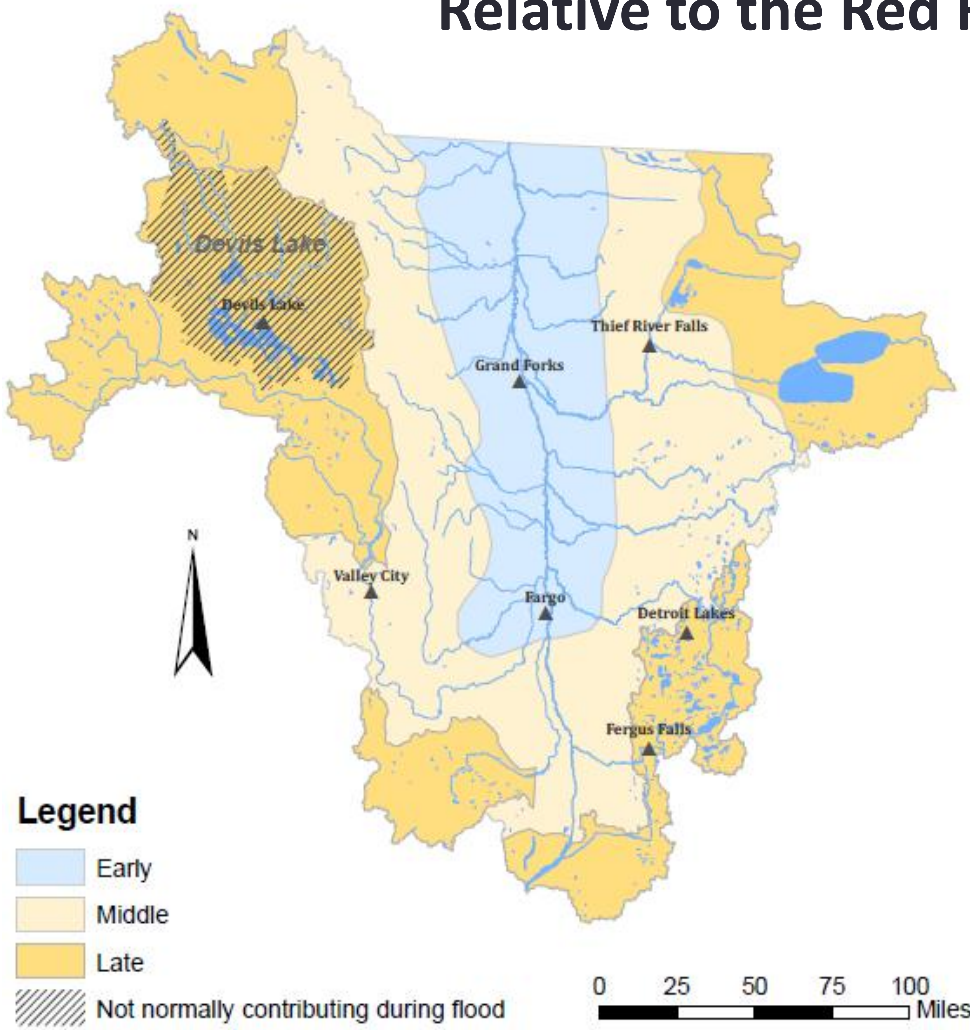
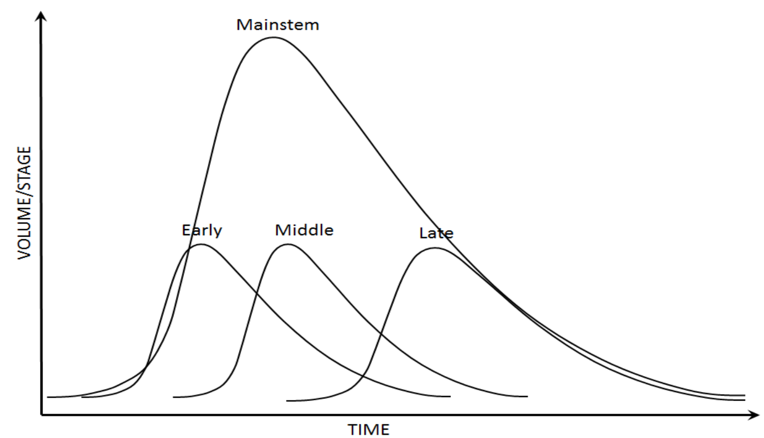
Early, Middle, and Late Water Areas (Timing)

Relative to the Red River Mainstem





Sources:

1) RRB TSAC, TP#11, *RRB Flood Damage Reduction Framework*, May 2004
2) RRBC, *RRB Long-Term Flood Strategy*, September 2011

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Unmanaged Subsurface Drainage Effects on Mainstem Peak Flows

Effect	Early Water	Middle Water	Late Water
Increased Volume	(-)	(- -)	(-)
Delayed Peak	(-)	(- or +)	(+)
Decreased Peak	(+)	(+ +)	(+)

Note: (+) Beneficial and (+ +) more beneficial to mainstem flood reduction;
(-) Detrimental and (- -) more detrimental to mainstem flooding

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Options (permitting / management)

1. **Field Outlet Control** (BTSAC preferred)
2. **Water Storage Trading** (BTSAC preferred)
3. **On- or Off-Site Storage**
4. **Culvert Sizing**
5. **Drainage Coefficient Limitations**

Early, Middle, Late Area Effects of Options on Mainstem Flooding

Options	Early Water	Middle Water	Late Water
Preferred - Field Outlet Control	Reduce	Reduce	Reduce
Preferred – Water Storage Trading / Bank	Reduce	Reduce	Reduce
Subsurface Drainage Coefficient Limits	Increase	Reduce	Reduce
Off/On-site Storage Option	Reduce*	Reduce	Reduce
Culvert Sizing	Increase	Reduce	Reduce

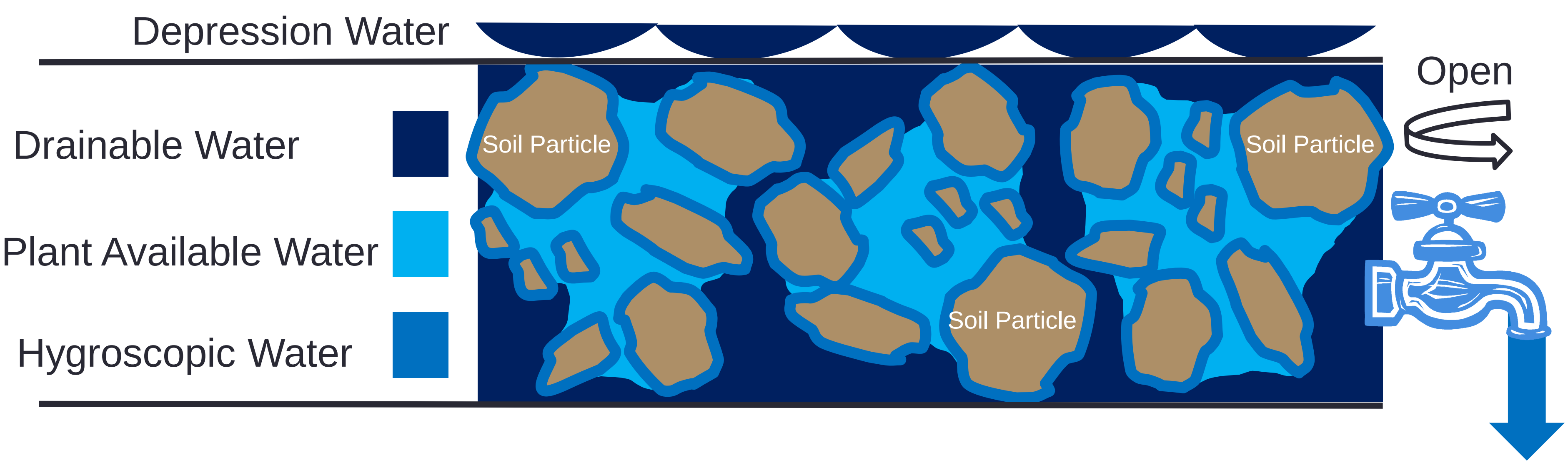
*Assumes gated storage. Ungated storage would increase potential in Early Water areas.

Water Management Objectives

- **Producer (Field and Farm scale)**
  - **Optimal Crop Production**
    - Remove excess water during wet periods (planting, harvesting and growing seasons)
    - *Conserve water during droughts*
- **Watershed/Basin Managers**
  - **Reduce flood flows (spring/summer events)**
    - Minimize flood damages

Subsurface Drainage Management

FALL SEASON



✓ ***As conditions allow***, subsurface drains can be opened to drain the soil profile and surface depression water in preparation for a spring flood event.

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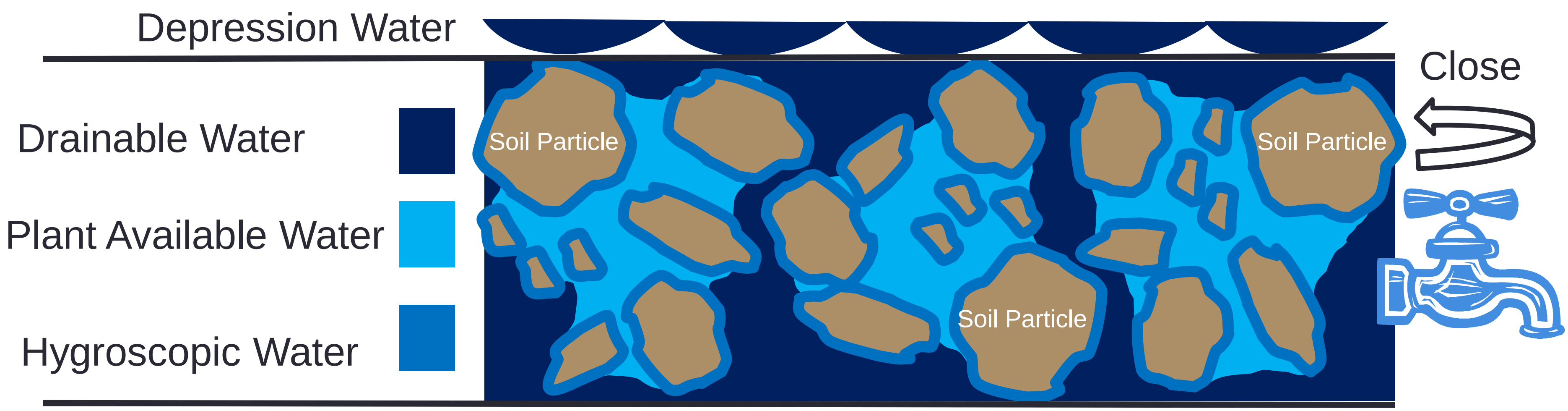
Subsurface Drainage Management

SPRING (flood) SEASON



✓ ***As conditions allow***, subsurface drains can be closed to store water during the spring flood event.

NEXT STEPS

- **Watershed scale GSSHA modeling** (in process, by BTSAC member Jim Solstad, DNR)
  - Verify or clarify Briefing Paper #2 Recommendations (if necessary)
- **Water Storage Trading/Credit Program**
  - Develop concept if requested / funded
- BTSAC provide additional technical assistance to Red River Retention Authority, when requested

"Intensified Tile Drainage Evaluation"
Science Museum of MN, St. Croix RS

- LCCMR project began 2009, completed summer 2012, but not yet published
- Evaluated 21 watersheds, with and without significant tile and surface drainage in southern and central MN
- Key conclusions:
  - Flow and runoff ratio increased > 50% in ~ half of watersheds
  - Largest increases correlate with extent of drainage (key) and soybeans which displaced, pasture, hay, and small grain
  - Drainage of depressions and wetlands reduces ET and increases runoff, which strongly correlates with increased river flows
  - Rivers with increased flows have widened 10-40%

Need to better understand Geomorphology (AK)

Federal and State Drainage Water Management (DWM) Initiatives

- **USDA-NRCS** Environmental Quality Incentives Program (**EQIP**) <u>began DWM initiative in 2012 (flat rates)</u>
- **BWSR CWF** Conservation Drainage Management Program (**CDMP**) received additional $700,000 for <u>FY 13 DWM initiative (25% non-state share required)</u>
- Coordinated to use NRCS conservation practice stds.
- <u>Both federal and state</u> can now provide financial assistance for <u>control structures on new pattern tile</u>
- Federal and state programs do not pay for the pattern tile, except state will help replace existing open inlets

MN Clean Water Fund
Conservation Drainage Mgmt. Prog.

FY 2010
$200,000

FY 2011
$400,000

FY 2012
$1,000,000

FY 2013
$1,700,000

FY 2013: additional $700,000 for Drainage Water Management in coordination NRCS conservation practice standards

BWSR FY 2013

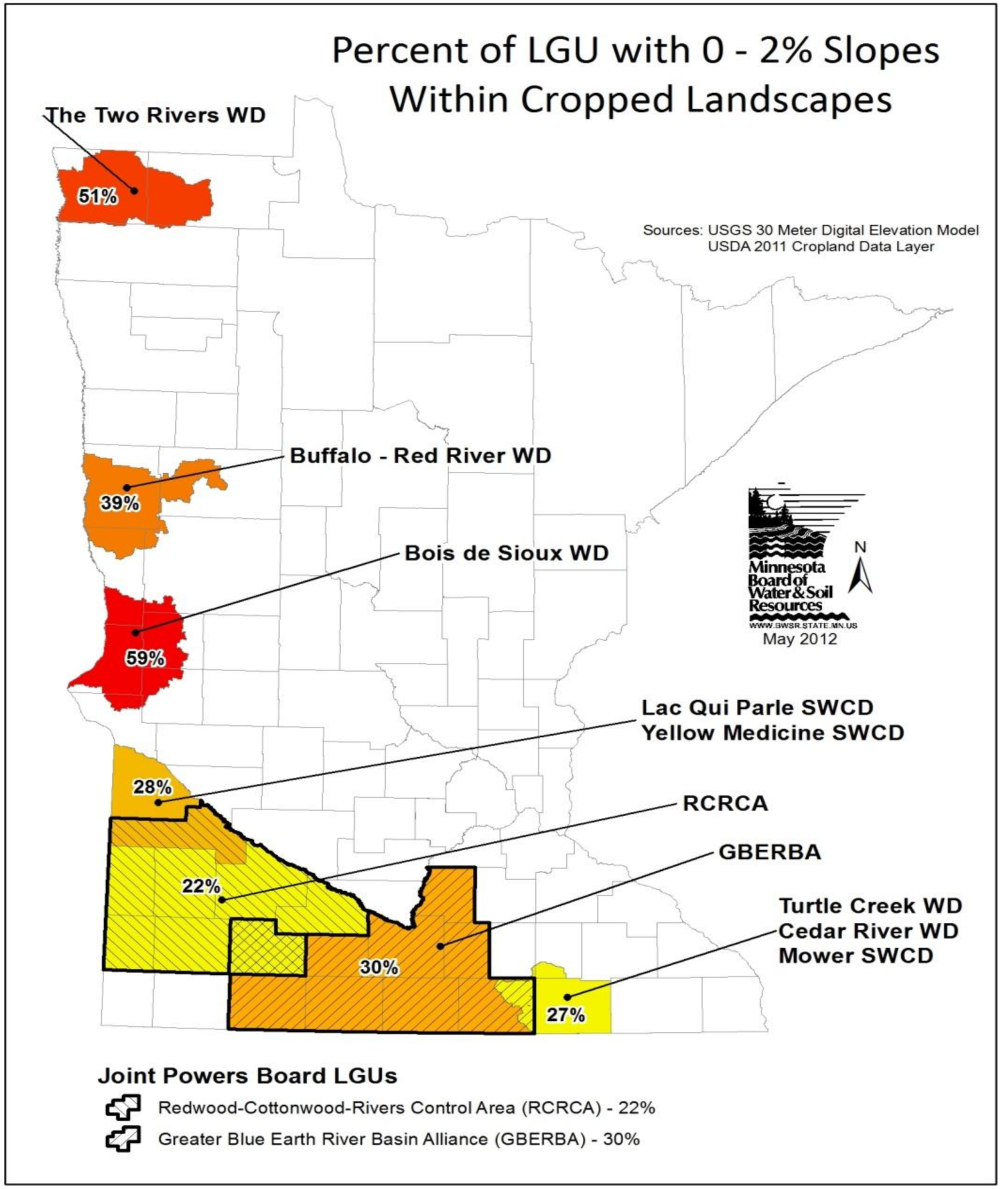
Targeted

Drainage

Water

Management

Grants

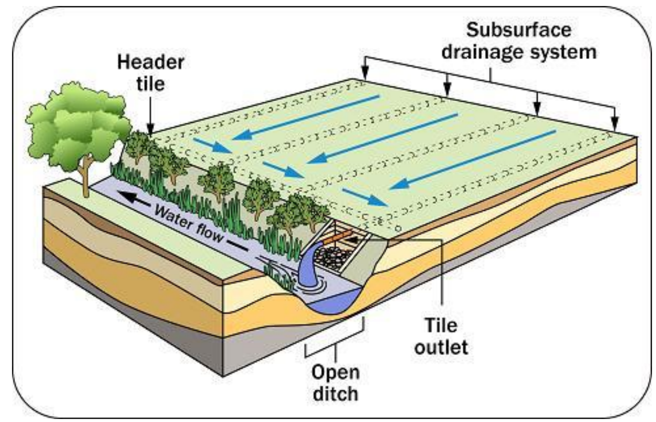


Eligible DWM Practice
Controlled Subsurface Drainage

NRCS Conservation Activity Plan (CAP) 130 – Drainage Water Management by TechReg TSP

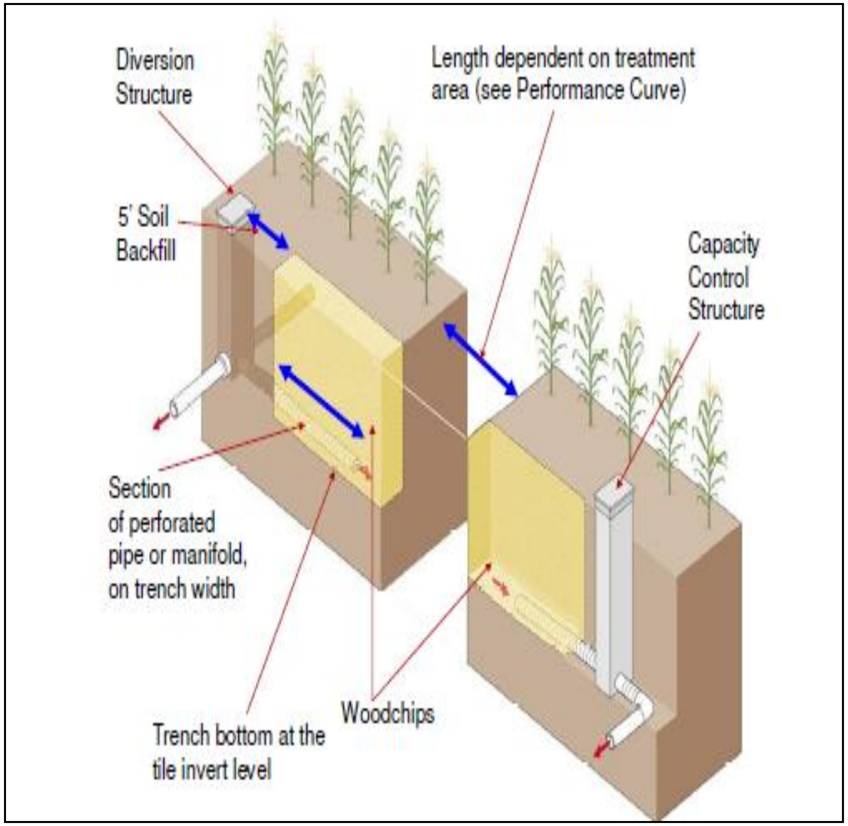
NRCS Practice 587 Structure for Water Control

NRCS Practice 554 Drainage Water Management, Implementation/Operation – CAP 130 is required. $7.58 per acre per year for the first three years of implementation and operation, up to 300 acres (State)



Eligible DWM Practice

Denitrifying Bioreactor



NRCS Interim Practice 747 Denitrifying Bioreactor

- Wood chips typical carbon source for bacteria and microbes that do denitrification
- A primary source of design guidance is **Illinois Drainage Guide**, Dr. Richard Cooke: Recent paper: “Protocol and Interactive Routine for the Design of Subsurface Bioreactors”
- Iowa NRCS also has spreadsheet
- BWSR and NRCS looking into how to provide training

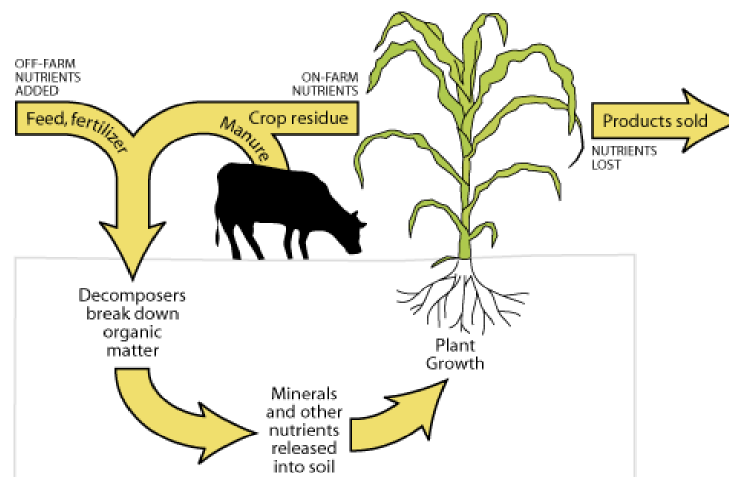
Eligible DWM Practice
Nutrient Management

NRCS Conservation Activity Plan (CAP) 104 Nutrient Management Plan

- On fields for which controlled subsurface drainage and/or a denitrifying bioreactor is planned.
- Plan must be developed by a NRCS TechReg certified Technical Service Provider (TSP)

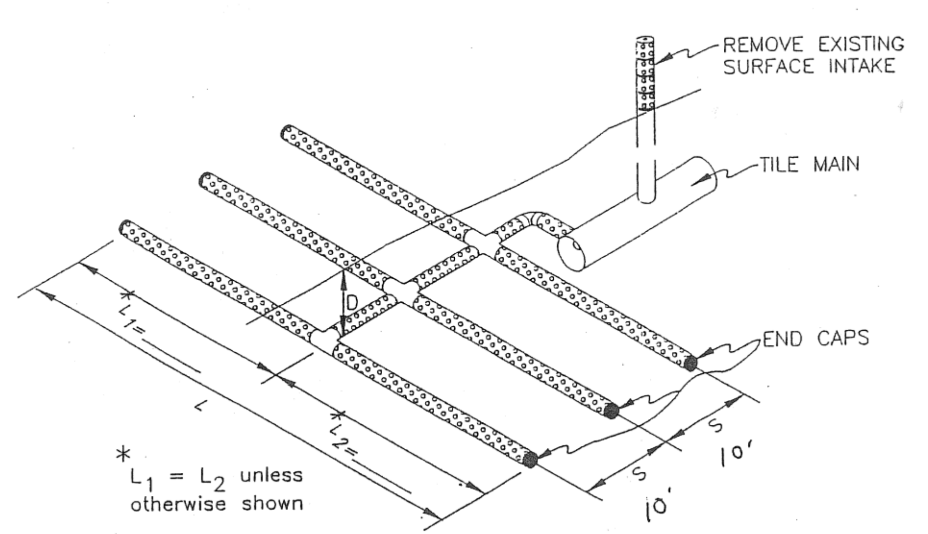
NRCS Practice 590 Nutrient Management

- On fields where controlled subsurface drainage, denitrifying bioreactor and/or existing open tile inlet(s) are replaced.
- A CAP 104 is required.
- Implementation incentive for the first three years at $5.44 per acre per year for CAP 104 acres without manure and $10.78 per acre per year for CAP 104 acres with manure, up to 300 acres (state).



Eligible DWM Practice

Replace Open Tile Inlets



Typical 50 ft. of tile per 0.1 acre of ponded area

Dense Pattern Tile

Gravel / Rock Inlet

CWF Conservation Drainage Mgmt. Program Additional Eligible Practices

- **i.e. in addition to DWM practices**
- **Multipurpose Drainage Management Planning** (only for Chapter 103E public drainage ditches)
- **Side Inlet Controls**
- **Buffers** adjacent to side inlets and tile inlets
- **Other innovative conservation drainage practices** that directly improve water quality, and/or manage runoff hydrology to improve water quality, and are practical and feasible

New Conservation Practice – Vegetated Subsurface Drain Outlet

- Interim Conservation Practice Standard 739
- aka Saturated Buffer
- First demonstration by Iowa State University starting in 2010
- First demonstration in Minnesota near Granite Falls on Doug Albin farm fall 2012

Re-Saturating Riparian Buffers In Tile Drained Landscapes

Dan B. Jaynes, USDA-ARS-National Laboratory for Agriculture and the Environment

and

Tom M. Isenhart, Iowa State University

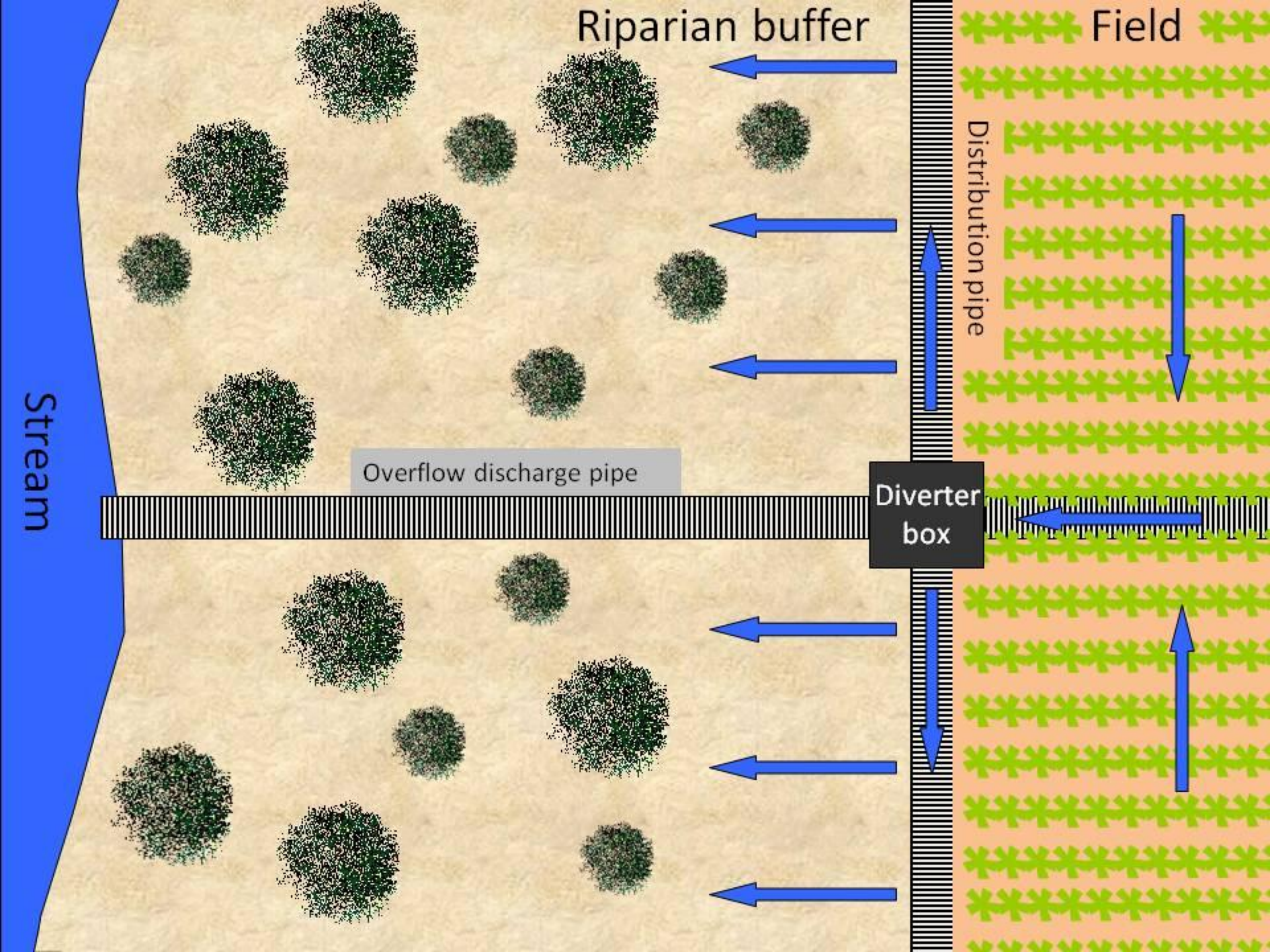
Natural Resource Ecology and Management

NLAE National Laboratory for Agriculture and the Environment

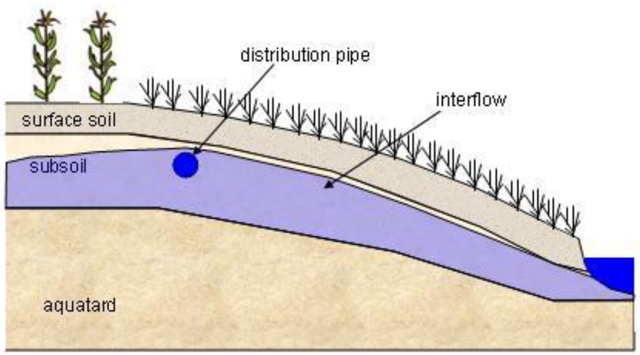
USDA 150 YEARS 1862-2012

Natural Resource Ecology and Management

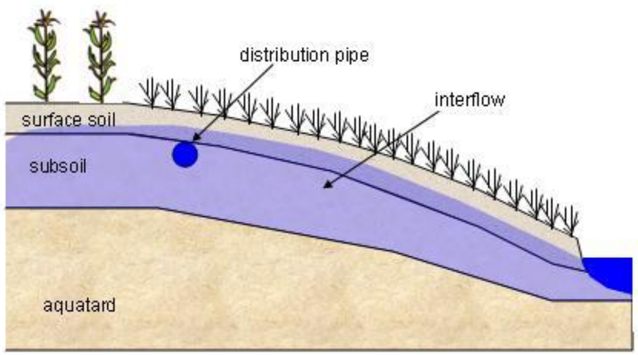
LEOPOLD CENTER


Riparian buffer
Field
Distribution pipe
Stream
Overflow discharge pipe
Diverter box

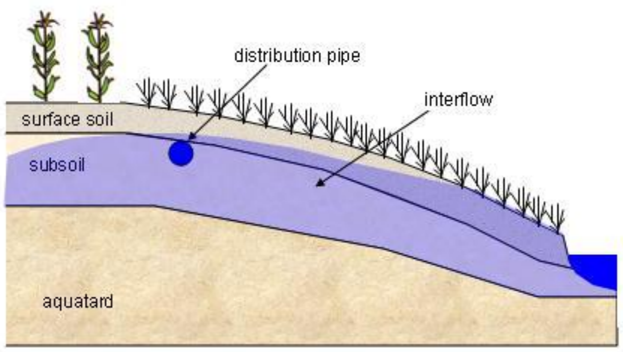
Induced Interflow



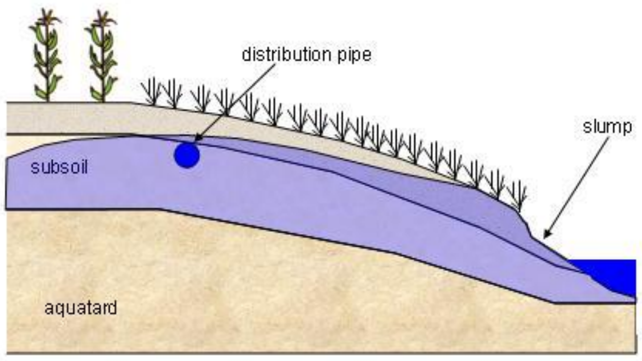
a) Enhanced uptake



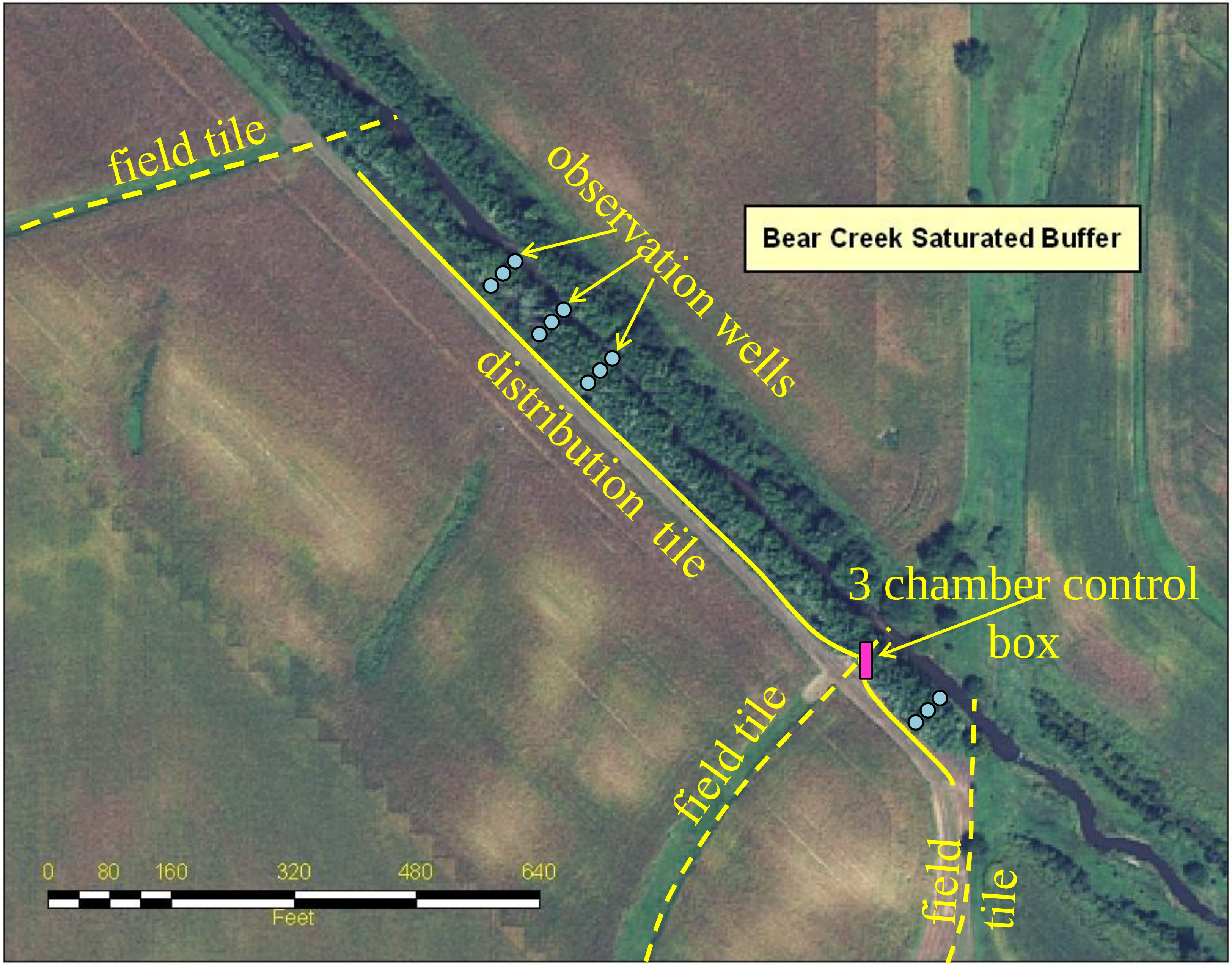
b) Enhanced denitrification



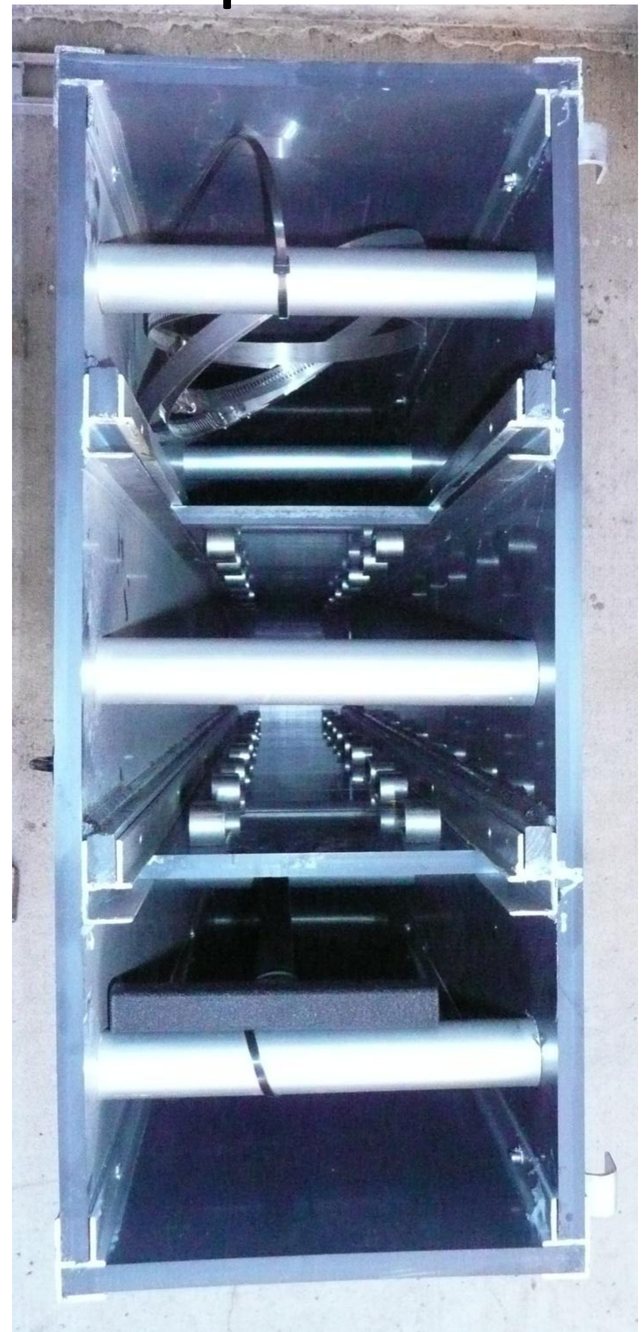
c) Surface discharge

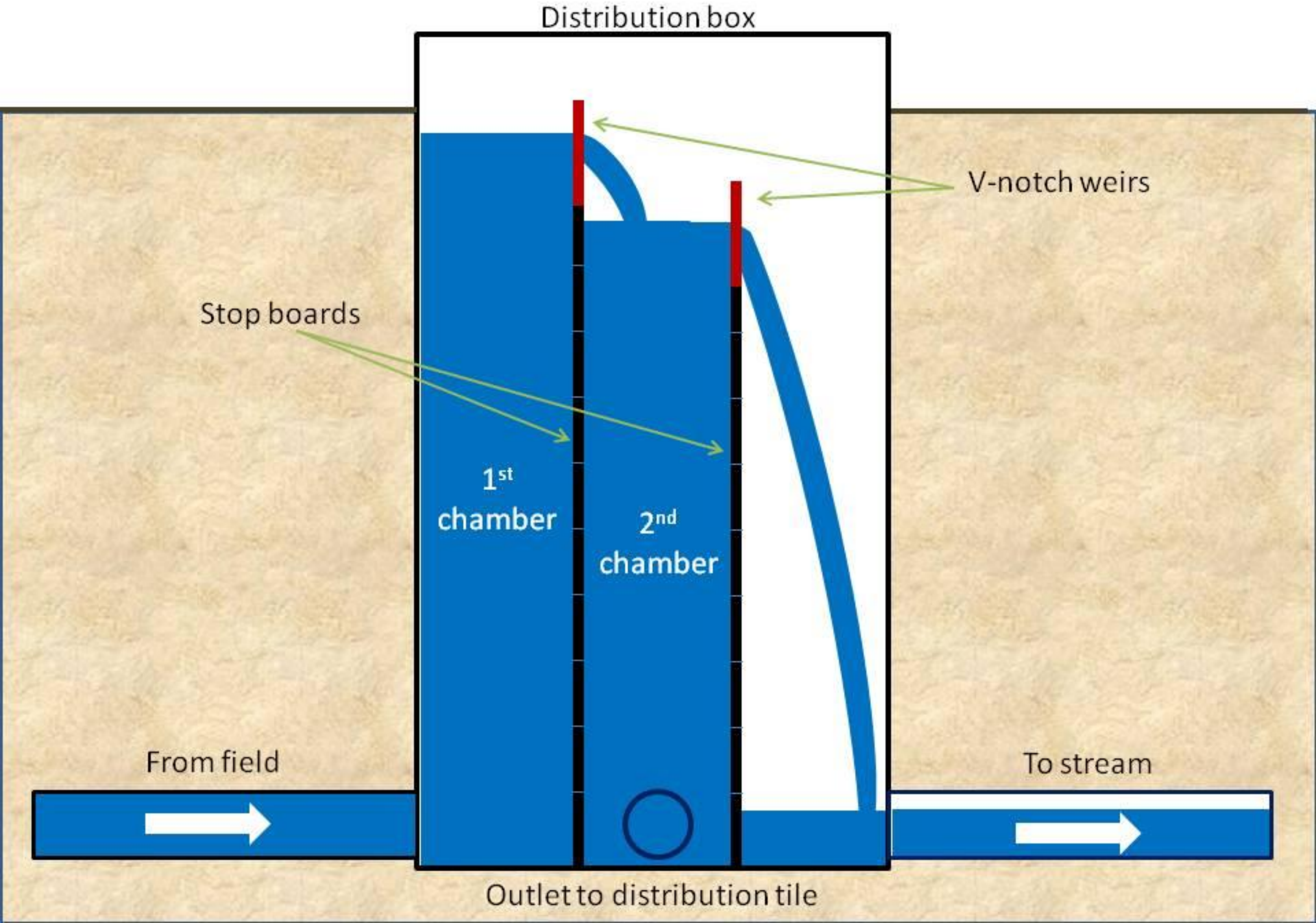


d) Channel slumping?

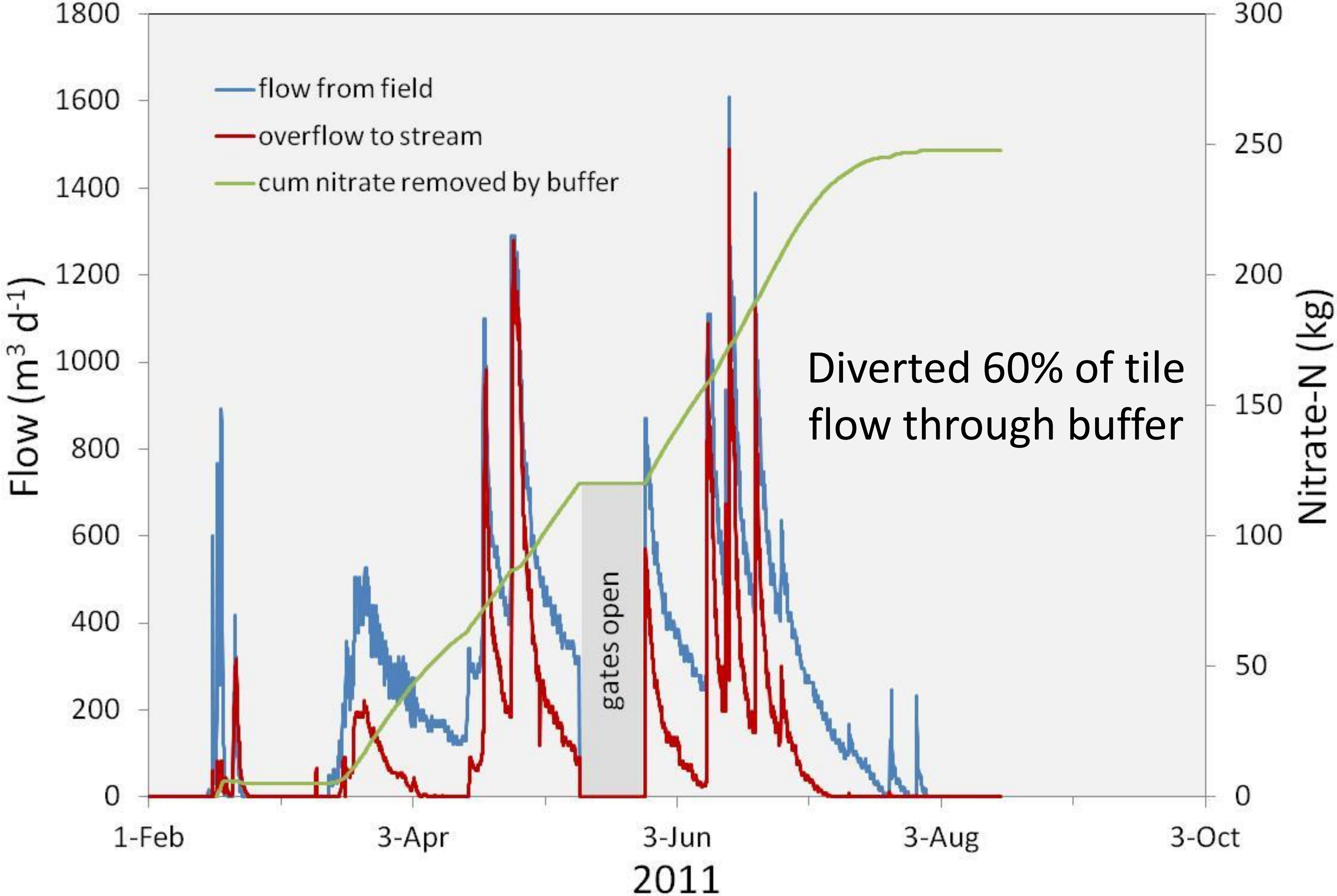

Bear Creek Saturated Buffer
field tile
observation wells
distribution tile
3 chamber control box
field tile
field tile
0
80
160
320
480
640
Feet

Top View




Distribution box
V-notch weirs
Stop boards
1st chamber
2nd chamber
From field
To stream
Outlet to distribution tile

1st Year Results



Diverted 60% of tile flow through buffer

Fate of Nitrate in Buffer

Transect #	Well #	Distance from tile (m)	Date - 2011 28-Feb	17-Mar	20-Apr	3-May	19-May	3-Jun	16-Jun	28-Jun	14-Jul	26-Jul
			NO_3 (mg N L^{-1})									
1	01	5.7	7.9	8.9	8.1	8.0	8.2	7.7	13.1	7.2	8.2	7.7
1	02	12.7	< 0.3	0.5	< 0.3	1.6	1.4	4.8	3.6	2.4	3.8	5.5
1	03	18.9	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
2	04	5.7	0.8	0.4	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
2	05	12.9	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
2	06	21.4	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	07	6.6	4.1	6.0	4.8	2.5	2.3	2.3	1.5	1.5	3.1	4.6
3	08	14.1	< 0.3	< 0.3	< 0.3	< 0.3	0.7	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	09	22.9	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
4	10	6.0	1.8	1.3	3.7	2.5	1.9	2.9	4.4	3.1	5.1	2.5
4	11	14.1	5.1	< 0.3	0.8	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
4	12	22.2	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
	Field		9.8	9.3	10.1	11.0	11.6	10.9	11.8	11.1	13.0	11.9
	Bear Creek		7.1	7.2	9.4	10.2	10.5	12	13.1	12.3	9.2	4.6

Essentially 100% of diverted tile flow nitrate was removed in the buffer

Economics

- For this example, 1000 ft of 4 in. distribution tile would cost $1250 @ $1.25 per foot installed.
- The control box for tile drainage diversion would cost $1000 installed. Another $100 would be required for design work.
- Assuming a 20yr life expectancy for the system at 4% interest would add about $2900 in opportunity cost.
- Thus, the total cost of the installation would be $5355 over 20 yr or $268 per year.
- 1st year nitrate removal at Bear Cr. was 550 lbs.
- This gives a cost of \$0.48 lbs^{-1} nitrate-N removed.
- Compared to constructed wetlands ($1.32/lbs) and fall planted cover crops ($3.08/lbs).

Bear Creek, Iowa Saturated Buffer Summary

- 1st year shows re-saturating riparian buffers can remove all the nitrate that is diverted into them.
- We were able to divert about 60% of the flow from a tile draining about 50 ac of field
- The cost of the practice is comparable to other N removal practices
- Practice shows potential of preventing > 11 million lbs of N from entering IA streams each year
- Currently expanding study by re-saturating 3 new sites in each of IA, IL, and IN (CIG – ADMC).

Questions?

Minnesota Board of Water & Soil Resources

CWF Conservation Drainage Mgmt. Program Practices Funded to Date

Funded Activity	FY 2010	FY 2011	FY 2012
Grade Stabilization Structure (CP 410) Side Inlets	2		5
Drainage Water Management (DWM)			
Conservation Activity Plans (CAP)			
CAP 130 Drainage Water Management Plan			
CAP 104 Nutrient Management Plan			
Denitrifying Bioreactor Interim (CP 747)	1	2	5
Drainage Water Management (CP 554)	3		1
Structure for Water Control (CP 587)	3		2
Subsurface Drainage (CP 606) Replace Tile Inlets	2		3
Culvert Sizing Master Plan		1	
Ag ditch Sediment Trap	1		
Tile Outlet down side of ravine			1