United States Department of Agriculture

NRCS Conservation Drainage Practices

Part 1: Saturated Buffer

Presented by:

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www.il.nrcs.usda.gov

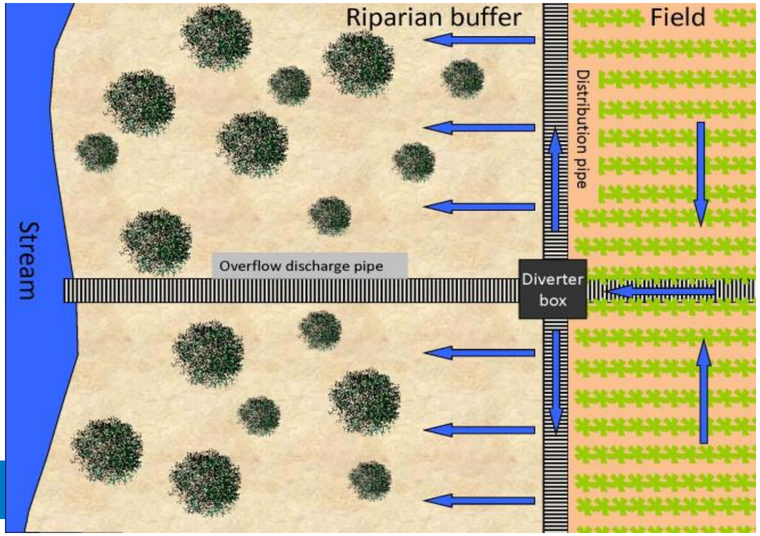
Illinois Sustainable Ag Partnership – June 14, 2018

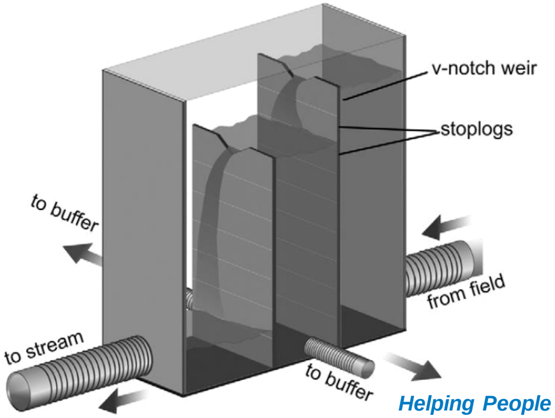
Agenda

- What the saturated buffer looks like and how it works
- Meeting the standard
- Determining feasibility

Saturated Buffer

- "Leach" tile water into the soil
- Let the soil provide the media for denitrification
- Let the vegetation uptake some nutrients



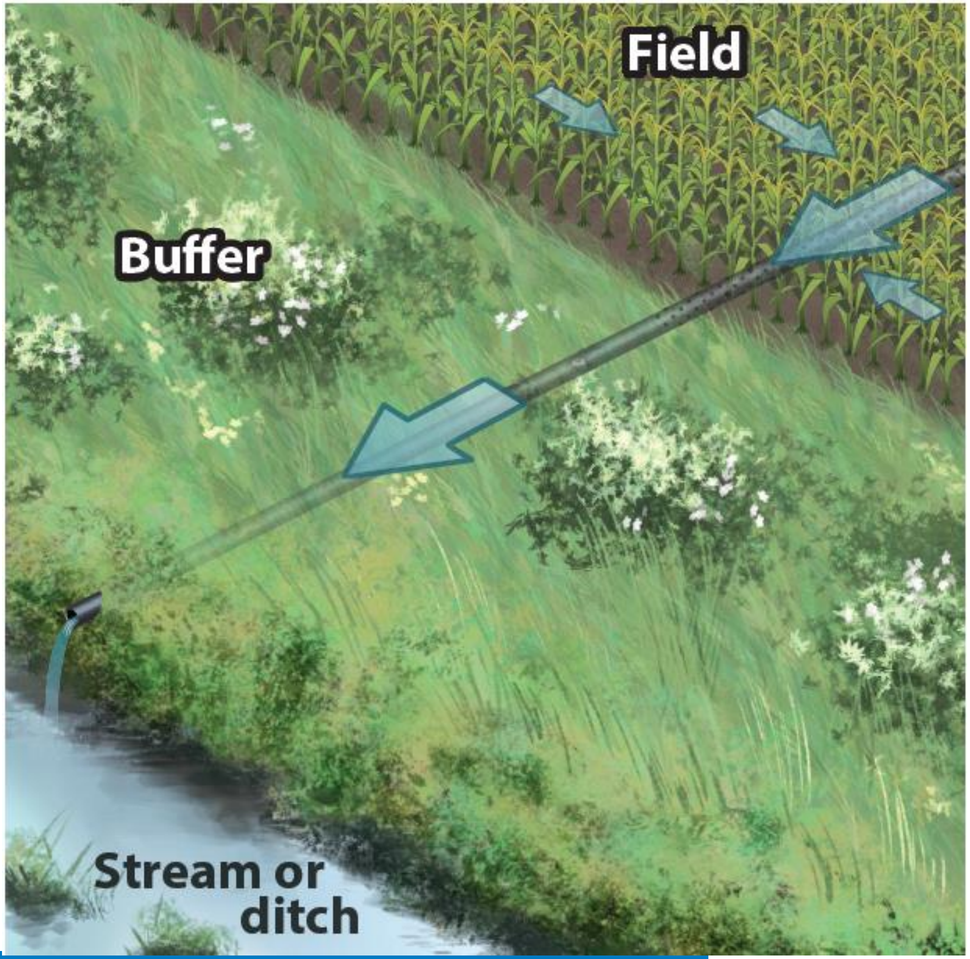


Saturated Buffer Contents

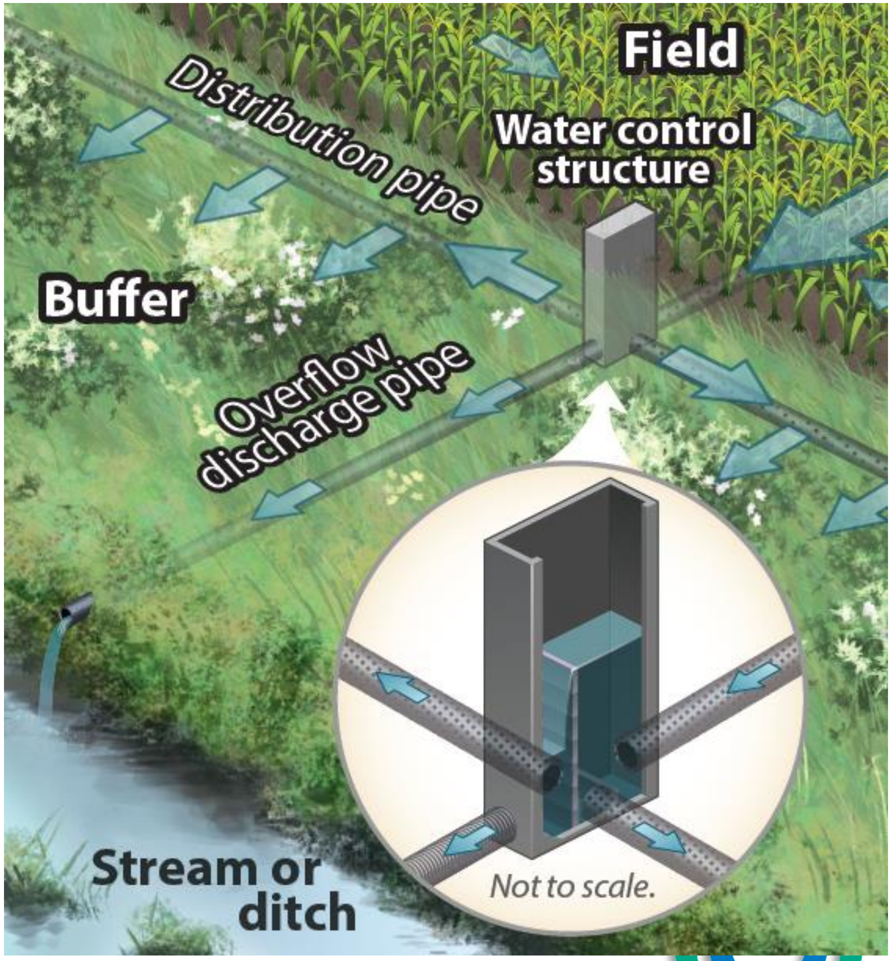
- A water control structure *(near the end of a tile line)*
- Distribution line(s)

Schematic

Conventional Outlet



Saturated Buffer



Courtesy: Purdue University

Photo courtesy Dan Jaynes, USDA-ARS)

Agenda

- What the saturated buffer looks like and how it works
- Meeting the standard
- Determining feasibility

NRCS Standard: Saturated Buffer

United States Department of Agriculture

604-CPS-1

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

SATURATED BUFFER

Code 604

(ft)

DEFINITION

A subsurface, perforated distribution pipe used to divert and spread drainage system discharge to a vegetated area to increase soil saturation.

PURPOSE

Install the practice to achieve one or more of the following purposes:

- To reduce nitrate loading from subsurface drain outlets.
- To enhance or restore saturated soil conditions in riverine, lacustrine fringe, slope, or depression hydrogeomorphic landscape classes.

CONDITIONS WHERE PRACTICE APPLIES

This practice is applicable to lands with a subsurface drainage system adaptable to discharge in a vegetated area.

Conditions Where Practice Applies

- Land with subsurface drainage (that can be adapted to discharge into a buffer)
- Where a raised water table can be maintained without adversely affecting banks, neighbors
- Does NOT apply to any system with surface inlets!
- Not to be used for septic effluent or animal waste

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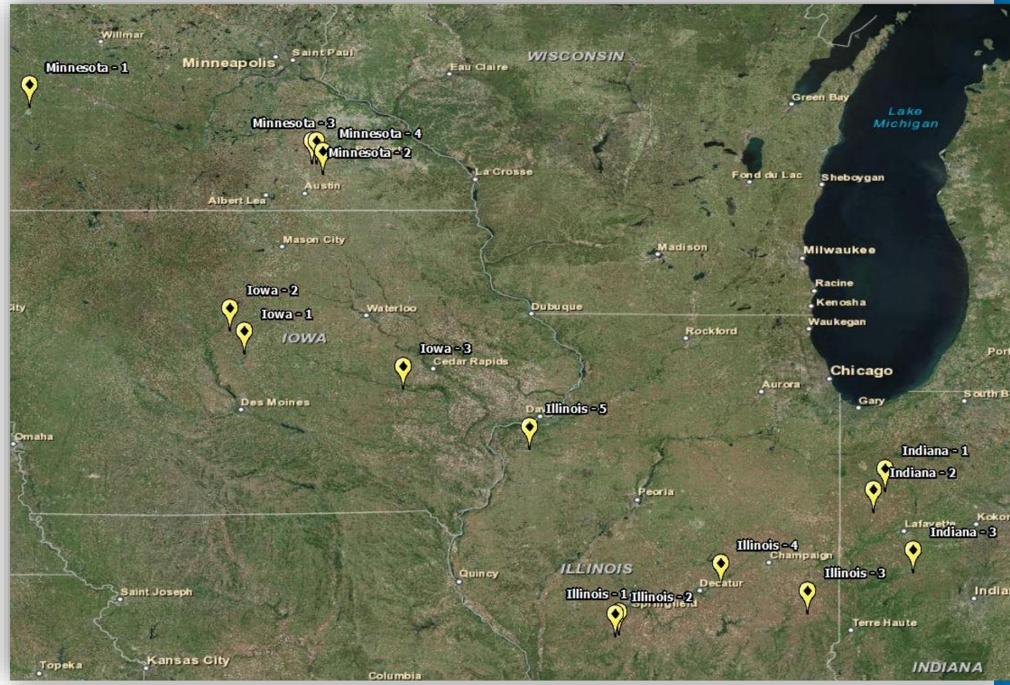
Criteria Development

Results	Number of Sites
Substantial nitrate removal	4
Promising in at least one year (2013-2015)	3
Insufficient data	3
Failure – did not remove nitrate	5

Several reasons for the failures:

- Coarse soil layers (couldn't maintain a water table)
- Inadequate soil carbon (no energy source for denitrifying bacteria)
- Improper design or installation
- High water levels in ditch



General Criteria

- Minimum width of vegetated buffer zone 30 feet

- *The vegetated buffer zone is defined as the area between the distribution pipe and the receiving channel on which permanent vegetation is maintained.*

General Criteria

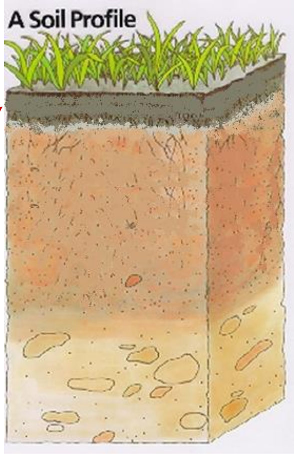
- Maximize “bang for the buck”

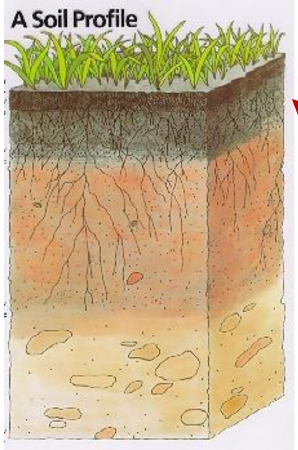
  (locate so you can treat as much subsurface drainage water as possible)

- No adverse impacts to neighbors

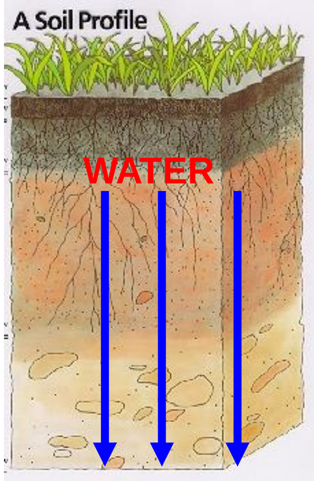
Unsuitable Site vs Suitable Site

Not much organic matter

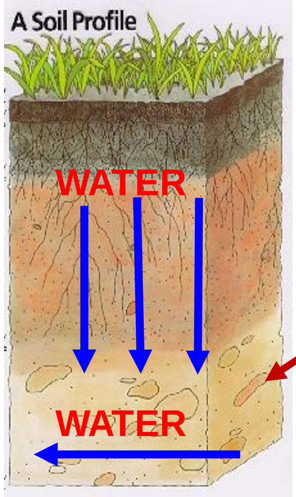




At least 1.2% O.M. in top 2.5 feet



Coarse gravel layer



Clay or moderately impermeable layer

Preplanning - Soil

- Presence of Organic Matter
- Capable of holding a water table
  - Poorly or somewhat poorly drained
  - Absence of sandy or gravelly layers?
- Hydraulic properties
  - Ksat
  - Drainable porosity

Prepare for the site specific geologic investigation

http://websoilsurvey.sc.egov.usda.gov

Criteria – Geologic/Soil Investigation

- Possible to hold a water table
- At least 1.2% organic matter in top 2.5 feet
- Abandoned pipes or tile?
- Depth to restrictive layer
- Hydraulic conductivity

Web Soil Survey

…and visual observation

Saturated Hydraulic Conductivity

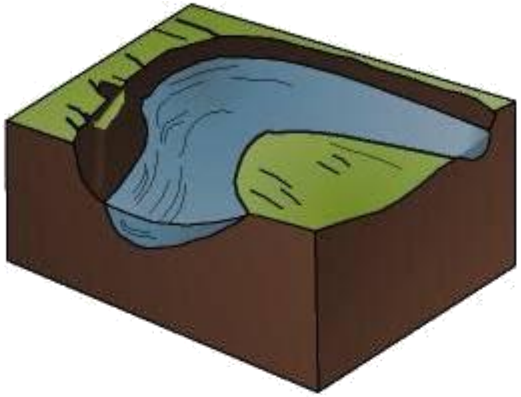
- Web Soil Survey?
- Guelph Permeameter
- Other methods

Soil saturated hydraulic conductivity, K_{sat} *(µm/sec)* | 9.17

0.11 ft/hr

Criteria - Bank and Channel Stability

- Visual assessment:
  - Bank issues
  - Downcutting channel
  - Lateral migration potential?
  - Incised >8 ft?



Q&A: What if the banks are > 8ft deep?

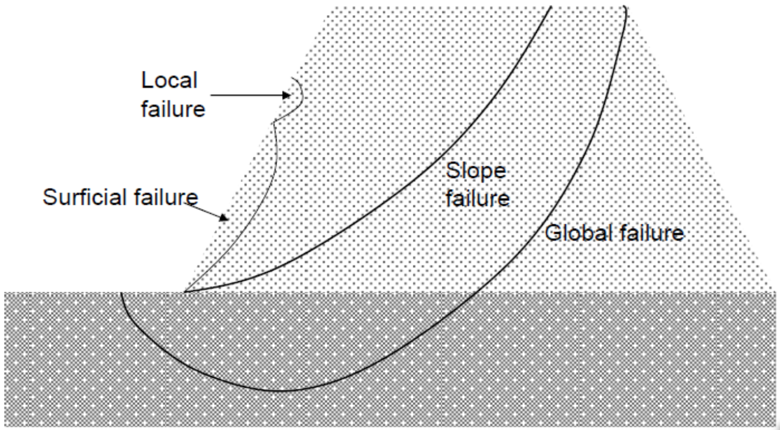
- Clay soils with Plasticity Index (PI) = 30 to 40 are stable on ~ 3:1 slopes
- Clays with PI>80 need more like 6.5:1

Streambanks seek their stable angle of repose. In a stable system, slopes on natural streams in these soil types reach a slope of from 4H:1V to 7H:1V, depending on the clay content and plasticity of the bank soils. Failures with highly plastic clay soils most often occur in streams modified by man or where streambed degradation has occurred, and the oversteepened slopes fail. These failures may not occur until many years following oversteepening of the streambanks.

NEH 654, TS 14A

So, what now?

- Geotechnical engineering is beyond the scope of this session.
- If you have a site with banks > 8ft and our triage indicates you might have a problem, consider one of these options:
  - Find a different site or pick a different conservation drainage option
  - Lay the bank back at a more stable slope (set the distribution line far enough back)
  - Stabilize the site first (CPS 580 – Streambank and Shoreline Protection)
  - Involve a geotechnical engineer
  - Use visual assessment option



Slope Stability Visual Assessment

CAUTION

- Beware – if restrictive layer is significantly higher than stream baseflow

Avoid placing the distribution pipe along any channels incised deeper than 8 feet, unless a slope stability analysis shows an acceptable level of safety against saturated streambank failure. Slope stability analysis may encompass geological investigations and reliance on local knowledge and field observations of bank stability and lateral migration potential. The latter method relies on signs that imply the bank does not exhibit an existing condition of slope instability, and has adequate slope and vegetation cover with a stream channel and does not show recent lateral shifting in the floodplain.

Criteria - Flow

- Minimum design flow 5% of max capacity of drainage system
    - Or as much as is practical based on available length of vegetated buffer

- How to determine if the buffer has adequate capacity
    - Use soil saturated hydraulic conductivity and hydraulic gradient
    - Other methods

Some history on the Capacity criterion

- Started as 15% (like the bioreactor)
- Very restrictive…very few sites would be able to meet the criterion
  - Capacity is determined by how much flow you can leach out through the soil from the distribution pipe (longer = more flow)
- Why have capacity criteria? ECONOMICS

Practice effectiveness and cost

In–field management practices   Edge–of–field structural practices   Land use changes

Nitrogen loss reduction practices	Reduction	Cost per acre	Cost efficiency in $ per lb N saved
Bioreactors on 50% of tile-drained acres	25%	$17	$2.20
Wetlands on 35% of tile-drained acres	50%	$61	$4.00
Buffers on all applicable cropland	90%	$294	$1.60

Saturated Buffers
$1.50 - $3.00

Special Note on Capacity

- Minor update to national standard (October, 2017)

Saturated Buffer (Code 604) – To expand the range of applicability of the standard to greater number of field sites, the current 5-percent flow capacity criteria for the saturated buffer is maintained, but designers are now allowed to use an alternate length of the distribution pipe if the 5-percent criteria is found impractical or cost-prohibitive. The required geological investigation for slope stability is also maintained, but designers are allowed an alternate analysis of slope stability based on professional, onsite observations.

Determining Drainage System Capacity

1. Mainline configuration (*tile size, type, grade* → capacity of outlet main)
2. Drainage Coefficient (Q = DC *inches/day* x acres drained)
   - With tile map (known drained area)
   - Without tile map (estimated drained area)
3. Modeling
   - Library of DRAINMOD runs for typical soil textures
   - Site specific modeling

Drainage System Capacity – Option 1

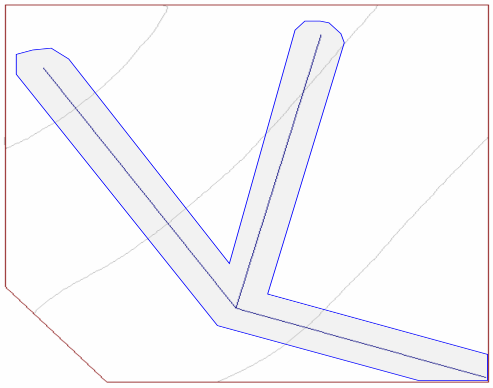
- Mainline configuration
  - Tile size and diameter
  - Tile grade
  - Roughness coefficient

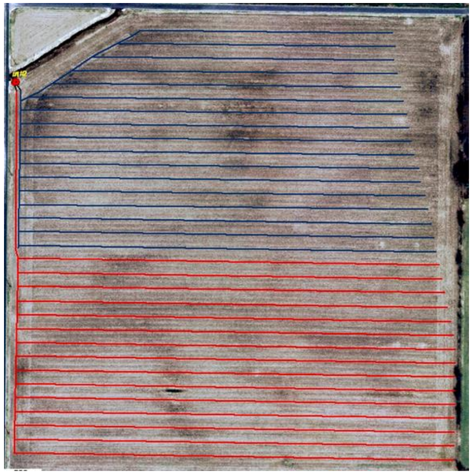
$$Q = \frac{1.486}{n} A\, R^{\frac{2}{3}} S^{\frac{1}{2}}$$

- Tends to be conservative

Drainage System Capacity – Option 2

- Drainage Coefficient method
  - **With tile map** – determine acres drained by the system
    - Find the drain spacing for the soil type and estimated depth, from the state Drainage Guide, and divide in half (**½S**)
    - Delineate drained acres by drawing a line around the tile system, **½S** on each side of the tile.
  - Then multiply drainage coefficient times drained acres *(with units conversions)*





Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48” depth 80-90 ft. Typical Illinois drainage coefficient = 3/8” per day.

Find drainage system capacity: *first, find area drained*

Area drained, ft^2 = *length* x *spacing*

Area drained =

Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48" depth 80-90 ft. Typical Illinois drainage coefficient = 3/8" per day.

Find drainage system capacity:

first, find area drained

Area drained, ft^2 = *length* x *spacing*

Area drained = (85)(3075) = 261,375 sq.ft. *(= 6.0 acres)*

Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48” depth 80-90 ft. Typical Illinois drainage coefficient = 3/8” per day. Remember our drained area calculation just now.

Calculations: *now find capacity of tile*

Capacity of tile Q, cfs = *coeff*. x *area* *(convert inches to ft; days to seconds)*

Capacity of tile $Q = \left(\frac{DC}{24\ x\ 3600\ x\ 12}\right)(DA\ x\ 43{,}560)$

Capacity of tile Q =

Option 2 - Example

Given:

Random tile system 3,075 ft long including lateral. Harpster soil: tile spacing for 48" depth 80-90 ft. Typical Illinois drainage coefficient = 3/8" per day. Remember our drained area calculation was 261,375 sq. ft.

Calculations: *now find capacity of tile*

Capacity of tile Q, cfs = *coeff*. x *area* *(convert inches to ft; days to seconds)*

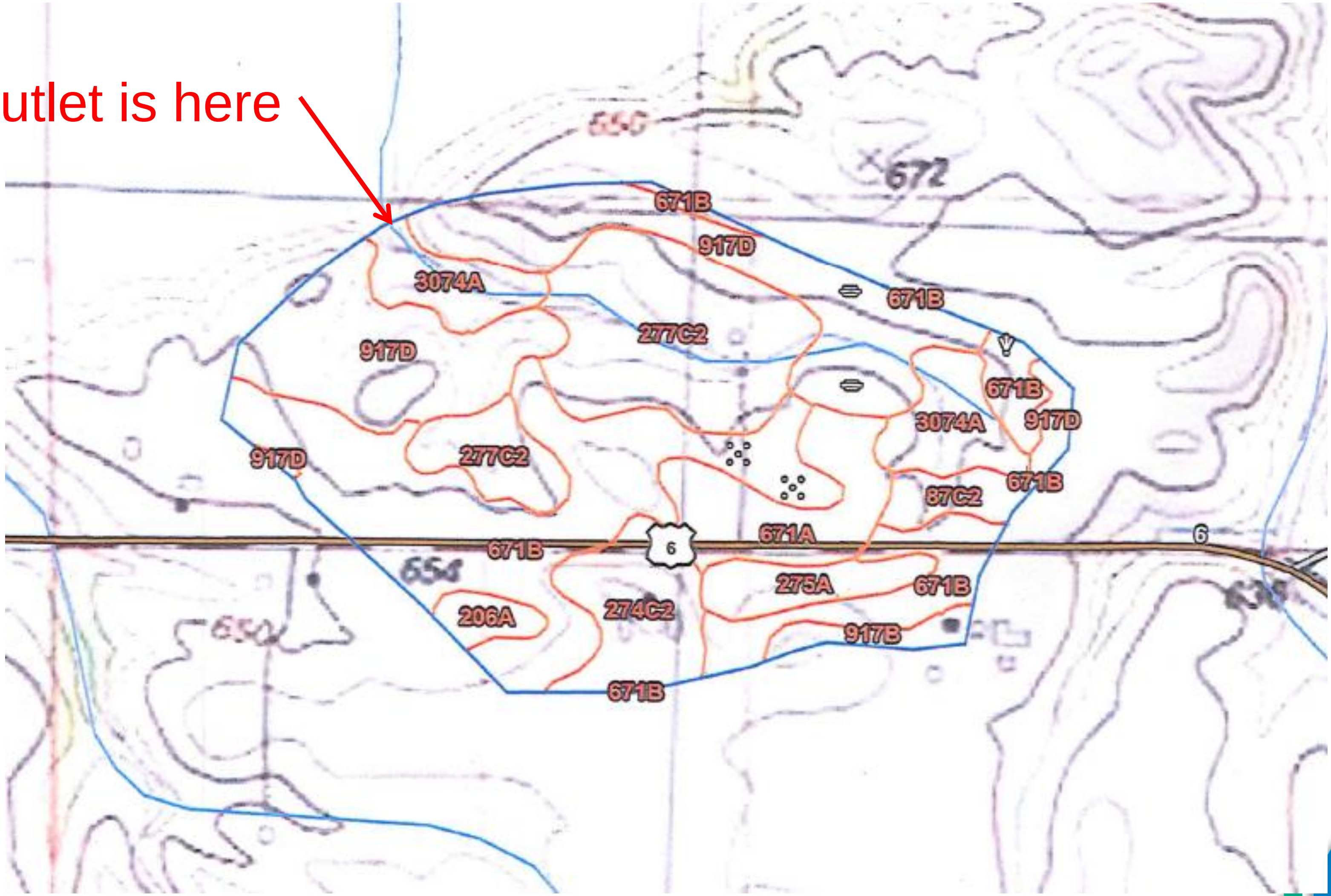
Capacity of tile $Q = \left(\frac{DC}{24\ x\ 3600\ x\ 12}\right)(DA\ x\ 43{,}560)$

$= \left(\frac{0.375}{24\ x\ 3600\ x\ 12}\right)(261{,}375)$ = 0.095 cfs

What if there is no tile map?

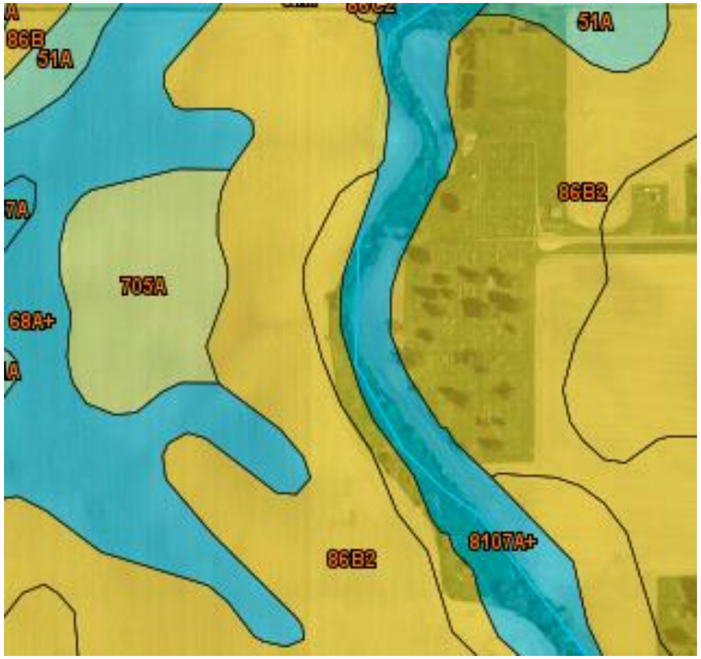
Acres Drained by Tile – Option 2, Method 2

Tile outlet is here



Acres Drained by Tile – Option 2, Method 2

- If you can't get a map of the tile system, delineate the entire watershed for surface flow to the tile outlet.
- Acres Drained = all of the watershed acres with poorly or very poorly drained soil, and half of the acres with somewhat poorly drained.
- Use Web Soil Survey to determine the soils in the watershed, and how many acres of each.



Soil Qualities and Features

- AASHTO Group Classification (Surface)
- Depth to a Selected Soil Restrictive Layer
- Depth to Any Soil Restrictive Layer
- Drainage Class

http://websoilsurvey.sc.egov.usda.gov

Option 2 – Example with no tile map

Given: *Typical Illinois drainage coefficient = 3/8" per day*

Soils in watershed:

Map Unit	Soil Name	Drainage Class	Acres
51A	Muscatine	Somewhat poorly drained	13.7
86B	Osco	Well drained	38.2
3107A	Sawmill	Poorly drained	51.9
		TOTAL	103.8

Find drained area and drainage system capacity:

Drained Area =

Capacity of tile $Q = \left(\frac{DC}{24\ x\ 3600\ x\ 12}\right)(DA\ x\ 43{,}560) =$

Option 2 – Example with no tile map

Given: *Typical Illinois drainage coefficient = 3/8" per day*

Soils in watershed:

Map Unit	Soil Name	Drainage Class	Acres
51A	Muscatine	Somewhat poorly drained	13.7
86B	Osco	Well drained	38.2
3107A	Sawmill	Poorly drained	51.9
		TOTAL	103.8

Calculations:

Drained Area = (.5 x 13.7) + 51.9 = 58.8 acres

Capacity of tile $Q = \left(\frac{DC}{24\ x\ 3600\ x\ 12}\right)(DA\ x\ 43{,}560)$

$= \left(\frac{0.375}{24\ x\ 3600\ x\ 12}\right)(58.8\ x\ 43{,}560)$ = 0.93 cfs

Design Flow

5% of Drainage System Capacity…figured whichever way you determine is appropriate

EXAMPLE:

Given: *Drainage system capacity = 0.93 cfs*

Calculation:

Design flow = .05 x 0.93 = 0.047 cfs

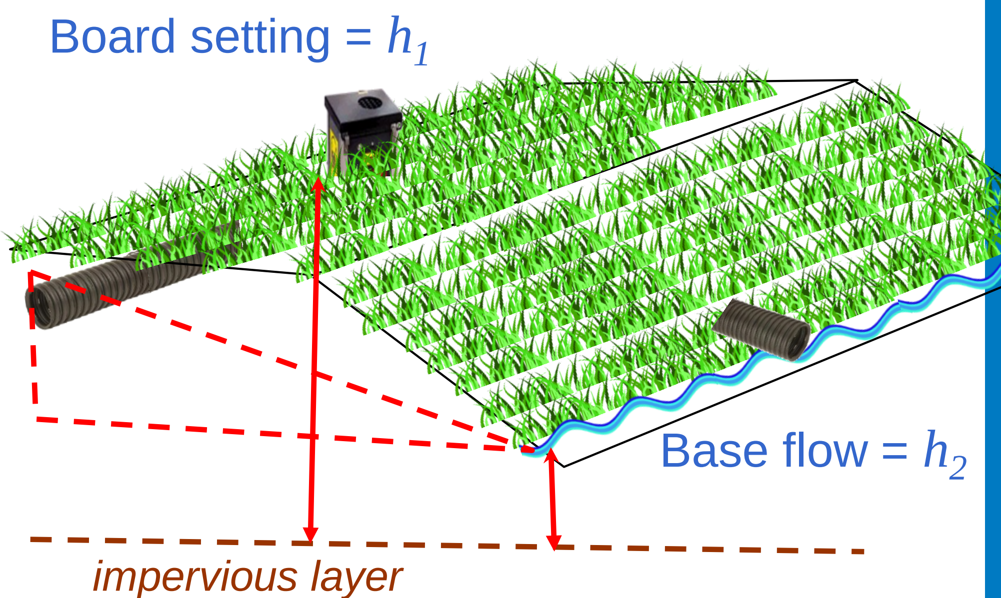

QUESTIONS

How to achieve the design flow?

- Unit flow per foot of “leach” pipe

$$q = \frac{K_{sat}}{2\,L}\left(h_1^2 - h_2^2\right)$$

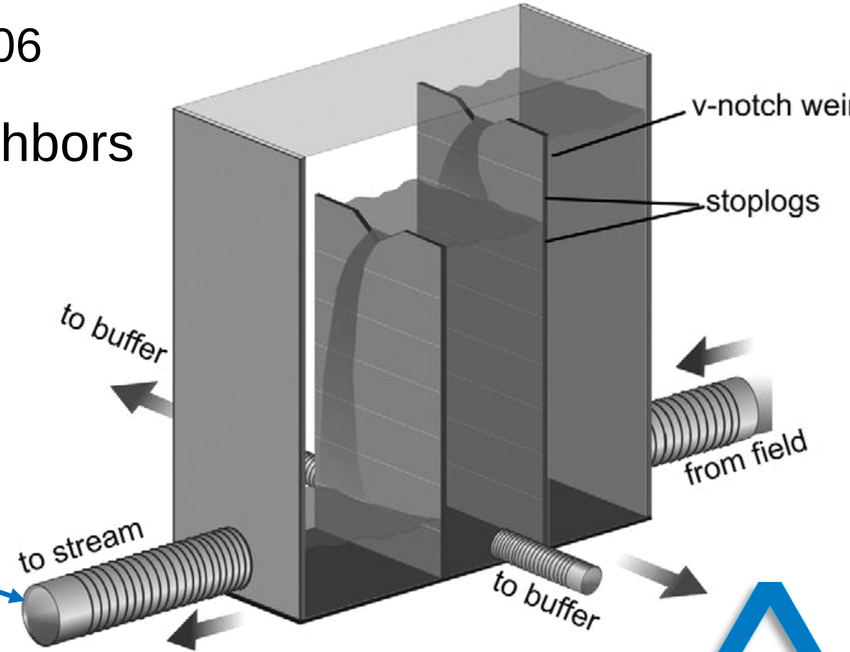
- Impervious layer closer to surface means less unit flow
- Maintain water table within 12” of ground surface @ distribution pipe



Criteria - Water Control Structure

- Water control structure (CPS 587) similar to drainage water management
- Nonperforated pipe for overflow
  - Avoid draining saturated soil zone
  - Comply with velocity criteria in CPS 606
- Remember: no adverse effect on neighbors

nonperforated at least 20’



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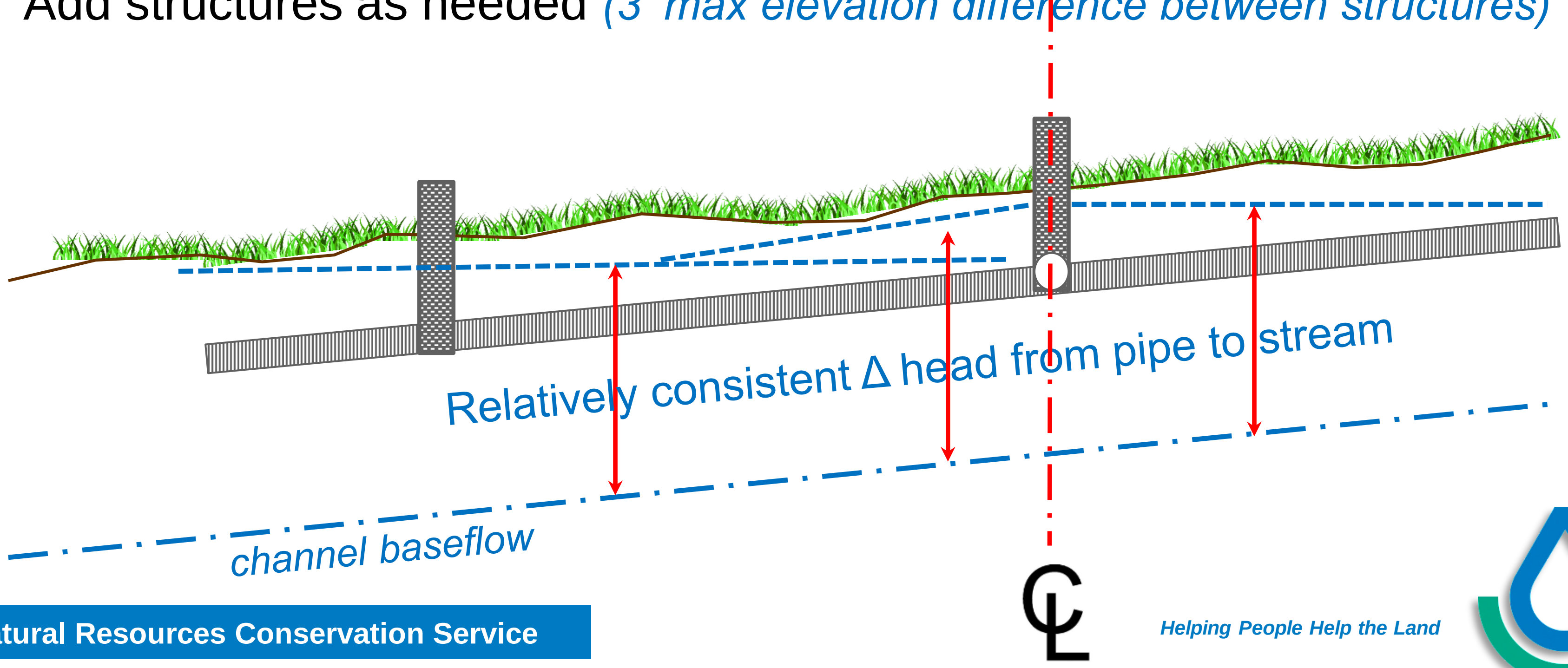
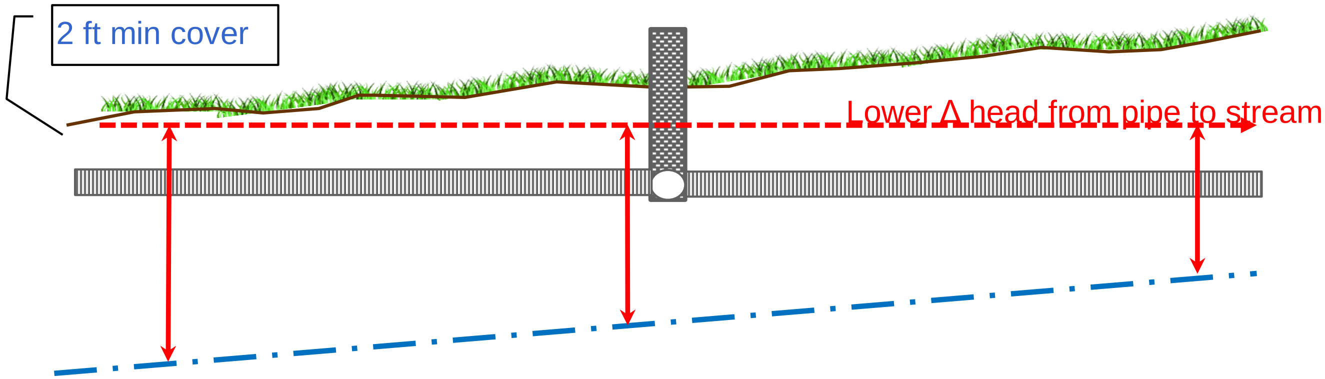
Criteria - Distribution Pipe

- Meet criteria for CPS 606 – Subsurface Drain
- Target is flow uniformity
- We analyze this 3-D problem in 2-D *(at the main water control structure)*
- Add structures as needed *(3' max elevation difference between structures)*

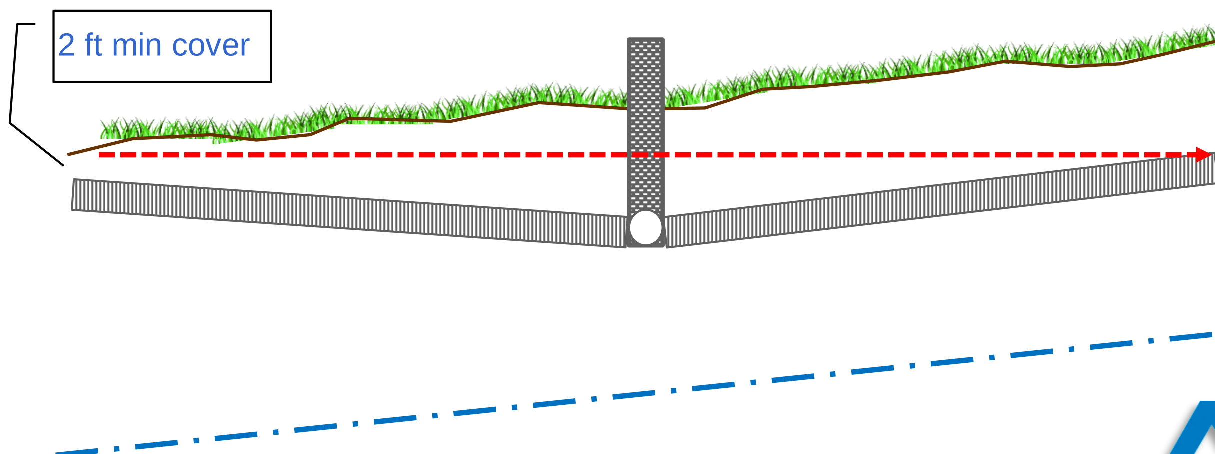


Other Distribution Pipe Layout Options

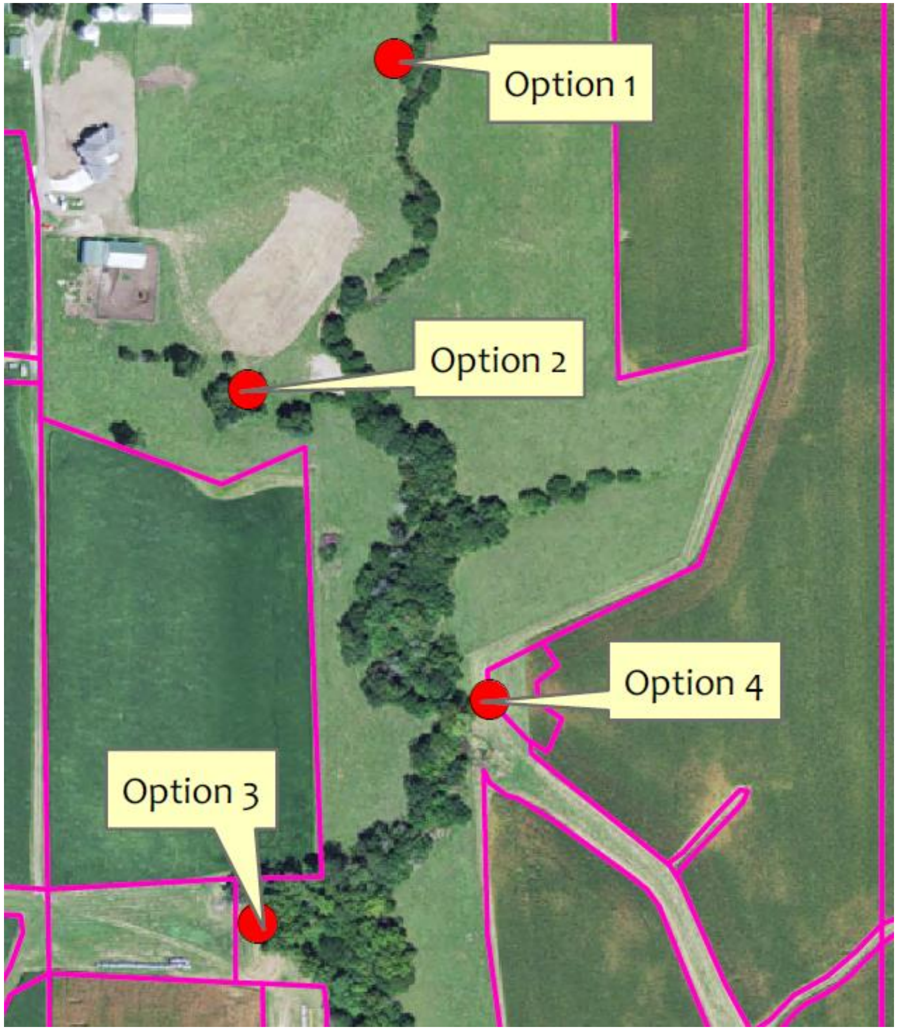
- Level

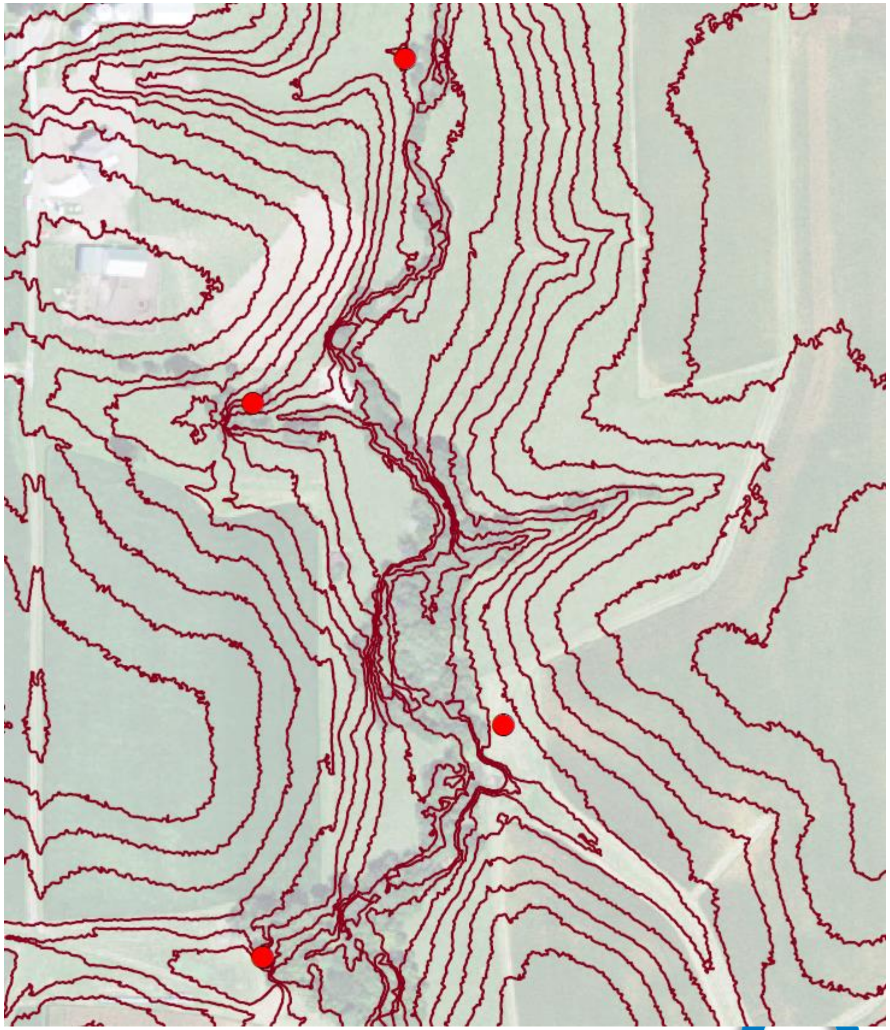


- Drain to structure



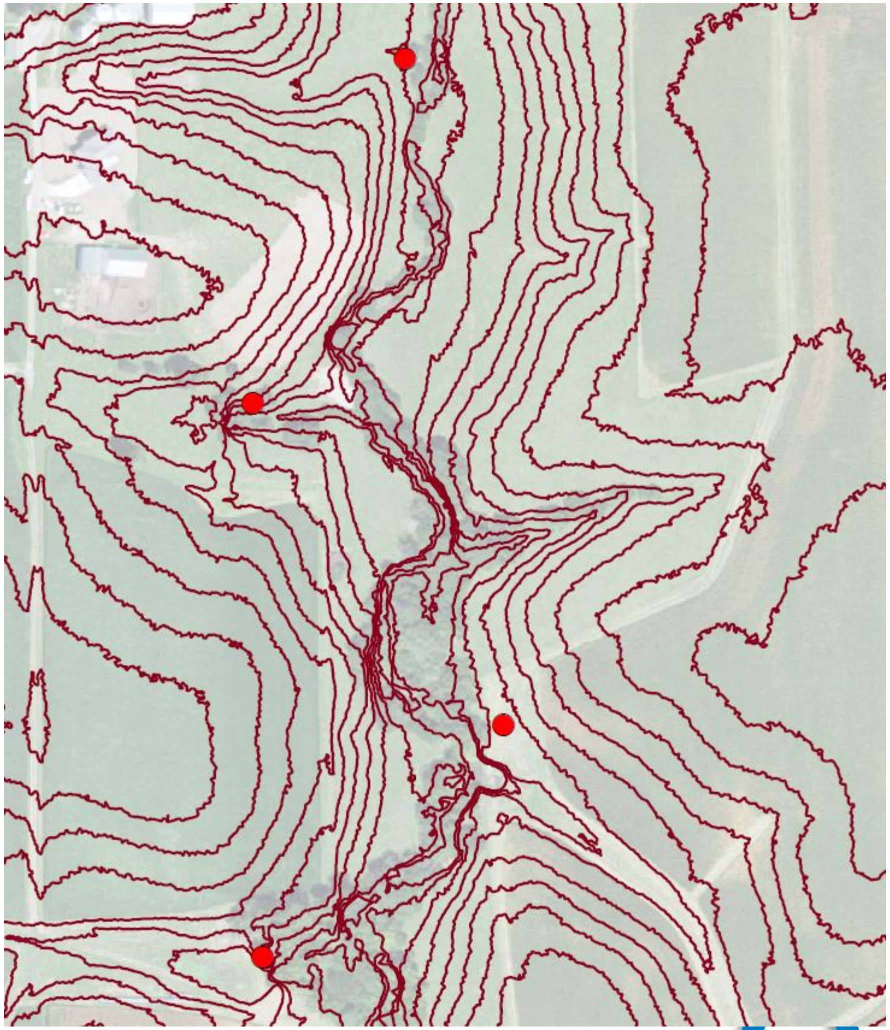
Preplanning - Topography





Q & A: What if we can’t get the uniformity?

- Divide the analysis into reaches
  - Similar distance from stream
    (± 10%~?)
  - Similar change in elevation from distribution pipe to stream
    (± 1.5 ft)
- Consider a different conservation drainage alternative

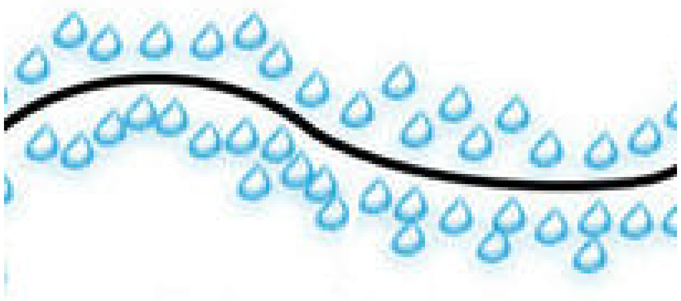


Sizing the Distribution Pipe Diameter

- The limitation needs to be flow through the soil, not flow through the pipe.

Think of it as a manifold with much larger potential input than output.

- IL standard drawings show 6” distribution pipe. This should be adequate for most situations.



Sizing the Distribution Pipe Length

- Assumes reasonably constant head differential and soil properties along the entire reach
- Need: at least 5% of system capacity
- Limitation will be flow through soil. How long will the pipe need to be? Given a unit flow, we can get more flow with a longer distribution pipe.

$$q = \frac{K_{sat}}{2\,L}\left(h_1^2 - h_2^2\right)$$

q = flow per unit length of distribution pipe
L = horizontal distance from pipe to receiving channel
h_1 = head at flash board setting (height above impervious layer)
h_2 = head at base flow in channel
K_{sat} = saturated hydraulic conductivity

Example – Distribution Pipe Length

Given: Required design flow to achieve 5% of drainage system capacity is 0.026 cfs *(33 acres, 3/8" drainage coefficient)*.

Calculations:

Unit flow through soil q = 0.099 ft^3/hr *per ft* *(from previous calculations)*

Total flow required (ft^3/hr) =

Distribution pipe length, ft = $\frac{Flow\ required}{Unit\ flow}$ =

Example – Distribution Pipe Length

Given: Required design flow to achieve 5% of drainage system capacity is 0.026 cfs *(33 acres, 3/8" drainage coefficient)*.

Calculations:

Unit flow q = 0.099 ft^3/hr *per ft* *(from previous calculations)*

Total flow required = 0.026 cfs = 93.6 ft^3/hr

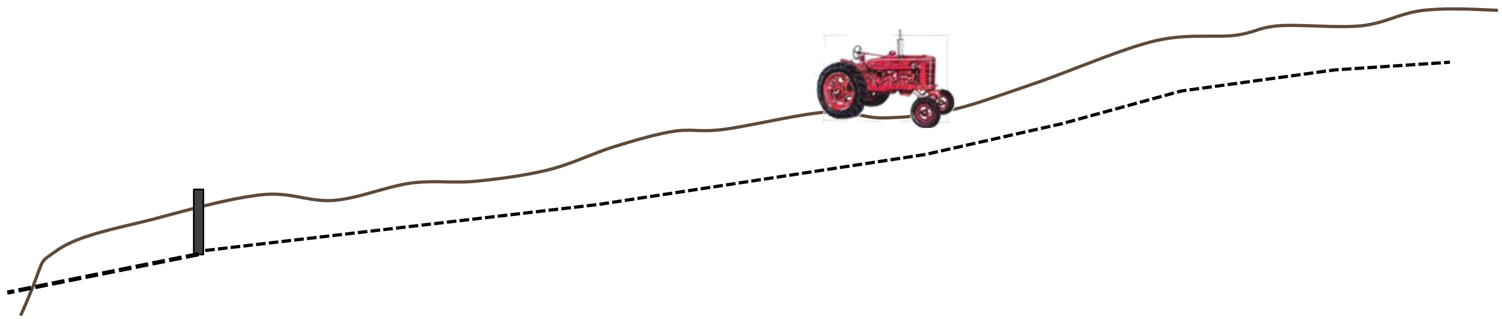
Distribution pipe length = $\frac{93.6}{0.099}$ = 945 ft

Criteria - Vegetative

- Can use Critical Area Planting (342) or Conservation Cover (327)
- If you're in an existing filter strip, check to see what the revegetation requirements are.

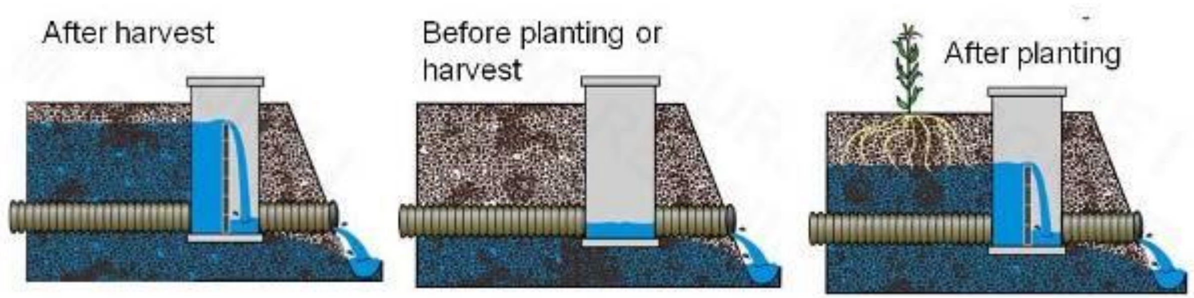
Set it and forget it?

- If topography allows, set saturated buffer lower in elevation so it can operate year round without affecting field trafficability.



Q & A: Can you do DWM with the saturated buffer?

- Yes!
- Suites of practices are highly recommended.
- If the site is relatively flat, some measure of DWM will likely be required.
- *May be able to hold back water and nutrients for crop production.*



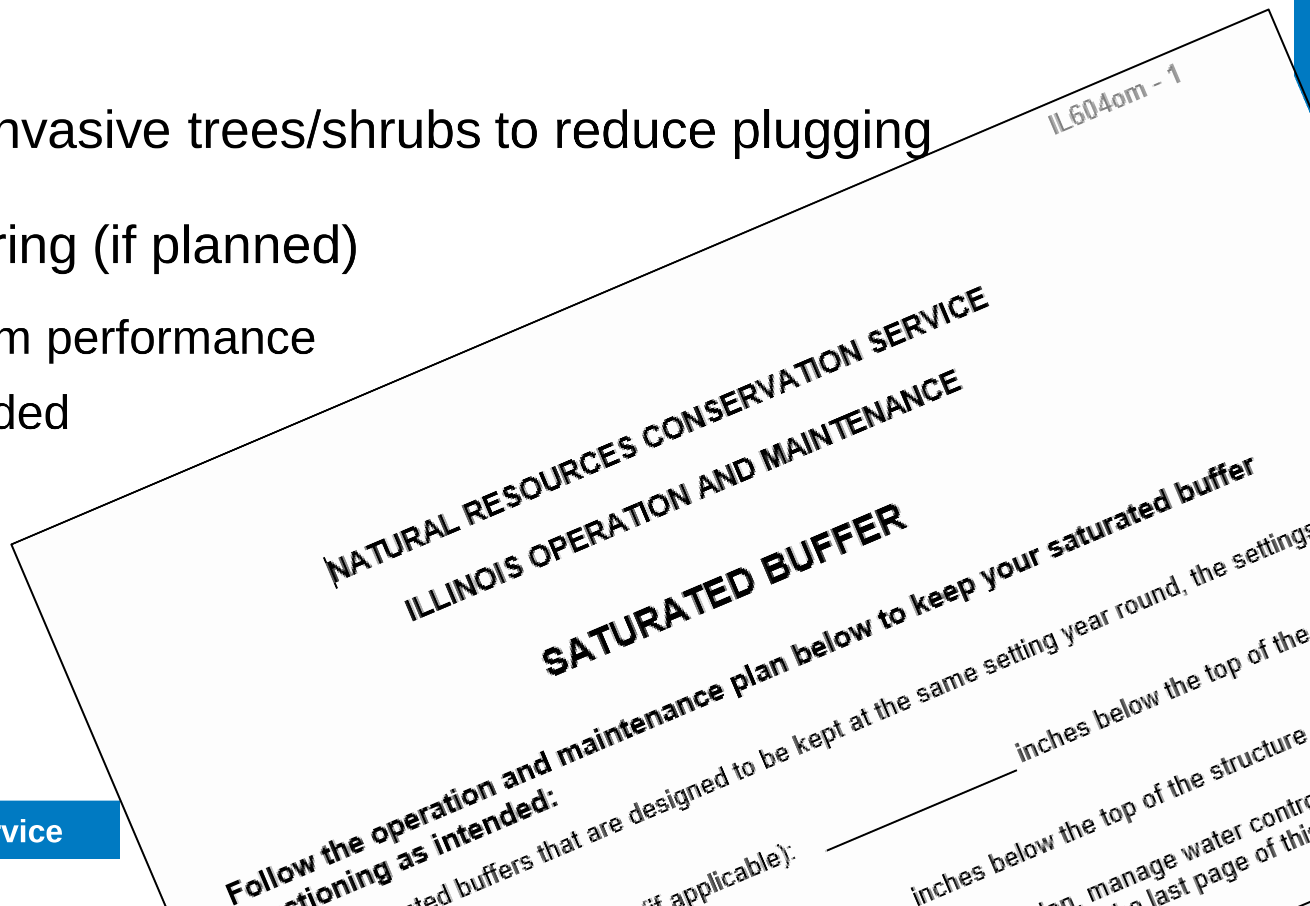
Plans and Specifications

- Plan view
- Profiles: existing drain, distribution pipe, outlet channel
- Structural details
- Vegetation establishment requirements
- Construction specs

See the Statement of Work for more details.

Operation and Maintenance

- Management information (water levels and timing)
- Inspection and maintenance requirements (both SB and contributing drainage system)
- Periodic removal of invasive trees/shrubs to reduce plugging
- Performance monitoring (if planned)
  - Demonstrate system performance
  - Improvements needed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NATURAL RESOURCES CONSERVATION SERVICE
ILLINOIS OPERATION AND MAINTENANCE
SATURATED BUFFER

Follow the operation and maintenance plan below to keep your saturated buffer ...tioning as intended:

...ted buffers that are designed to be kept at the same setting year round, the settings

...(if applicable): ______ inches below the top of the

inches below the top of the structure

Agenda

- What the saturated buffer looks like and how it works
- Meeting the standard
- Determining feasibility

Inventory & Evaluation (“I&E”)

- Is the site appropriate for a saturated buffer?
  - If not, is there a better site nearby?
  - Or is there a more suitable conservation drainage practice?

- Plan maps and quantity estimates so client can make planning decisions
  - Client preferences
  - Preliminary design alternative(s)

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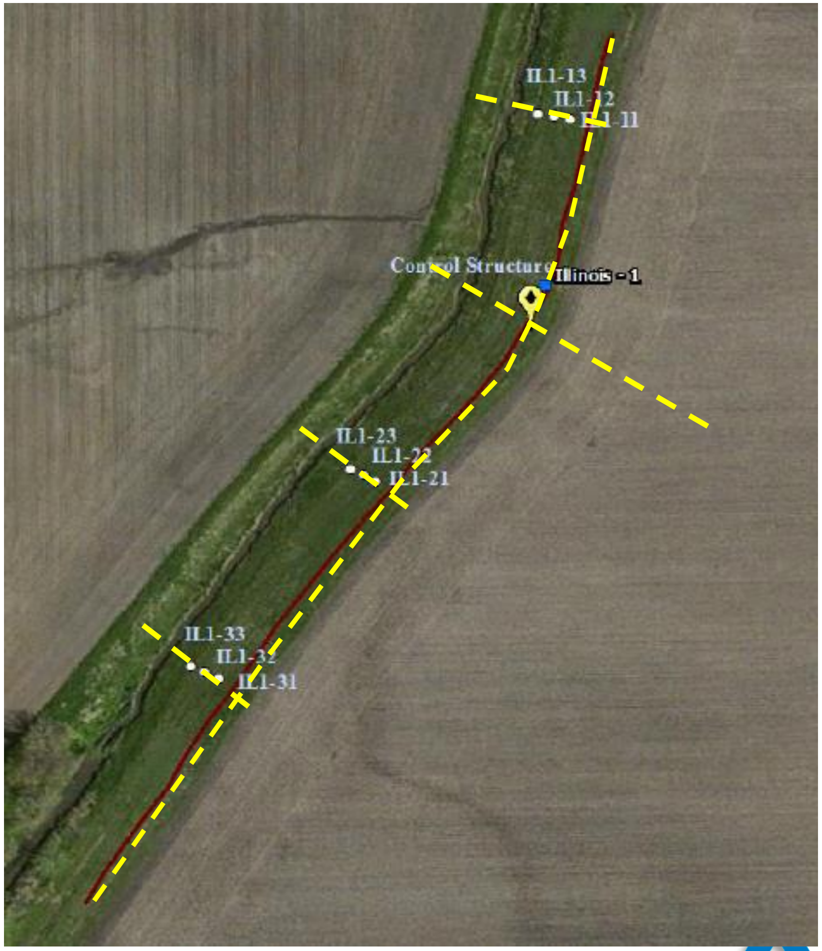
Saturated Buffer needs to fit the site

- Each site is different
- Factors to consider:
  - Control elevation
  - Bank stability
  - Property lines and infrastructure
  - Available buffer width (existing or proposed)

What is this?



Q&A: Any sites we should avoid?

- Subsurface drainage system must have NO surface inlets
- Soils need to be able to hold a water table and have enough organic matter
- Bank/channel must be stable
- Avoid locations where restrictive layer is significantly above channel flowline *(unless you can show bank stability)*

Q&A: Any sites we should avoid?

- Minimize flooding from receiving channel
- Avoid flooding the crops! (and neighbors)
- Avoid locations within drip line of trees (to reduce root plugging)

Saturated Buffer I&E info needed – basic

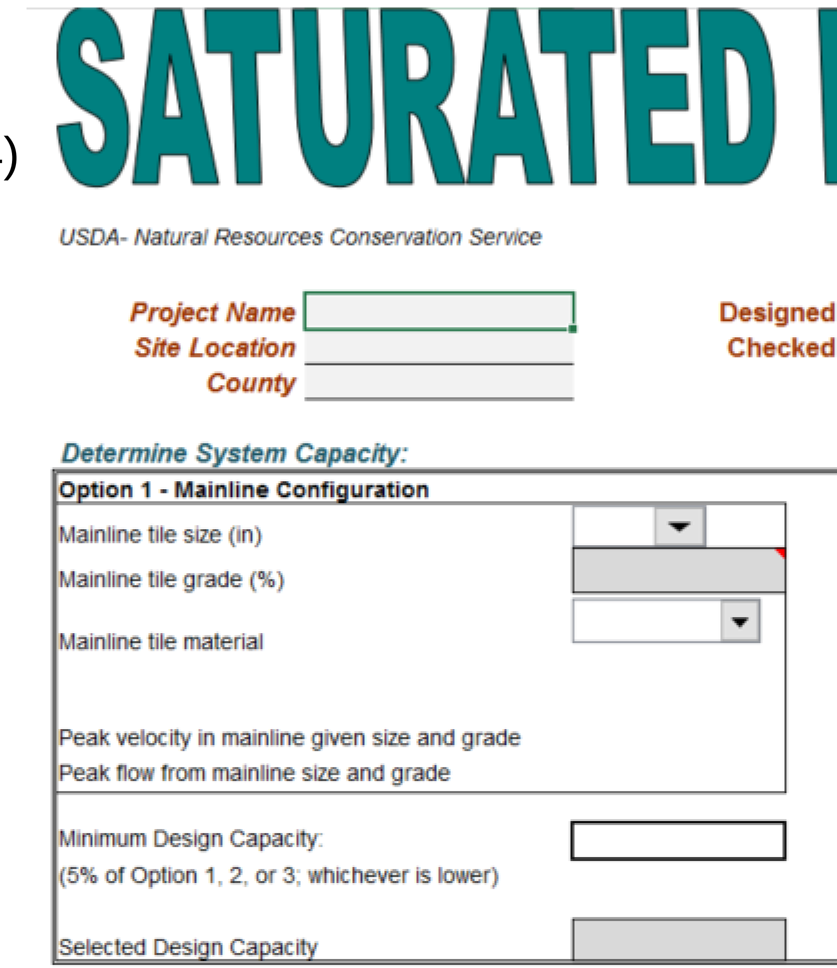
- ID info (county and client name, legal description/location)
- Is the land currently under a conservation program?
- Preferences of the client
  - Active or passive management?
  - Open to doing DWM as well?
- Will the site be used for monitoring/research?

Saturated Buffer I&E info needed - technical

- Maps
  - Aerial, with <u>property boundaries</u>, location of proposed practice
  - Topography/soils with drainage area delineated (LiDAR preferred)
  - Tile (or at least tile dia, depth, grade, location, surface intakes)
- Site conditions
  - Vegetation on site (photos?)
  - Crops/ proximity
  - Elevations (baseflow, crop, proposed buffer site, etc)
  - Receiving channel/ area (bank stability)
  - Geologic investigation
  - Any abandoned tile we need to be aware of?

NRCS Resources

- Related standards
  - Structure for Water Control (Code 587)
  - Subsurface Drain (Code 606)
  - Drainage Water Management (Code 554)
- Guidance document "how-to"
- Standard drawings
- Customizable construction specs and O&M documents
- Spreadsheet planning/design tool
- Info sheet




QUESTIONS

Equal Opportunity

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USDA
Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, S.W.
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