Saturated Buffers: A new approach for reducing nitrate transport from tile-drained fields

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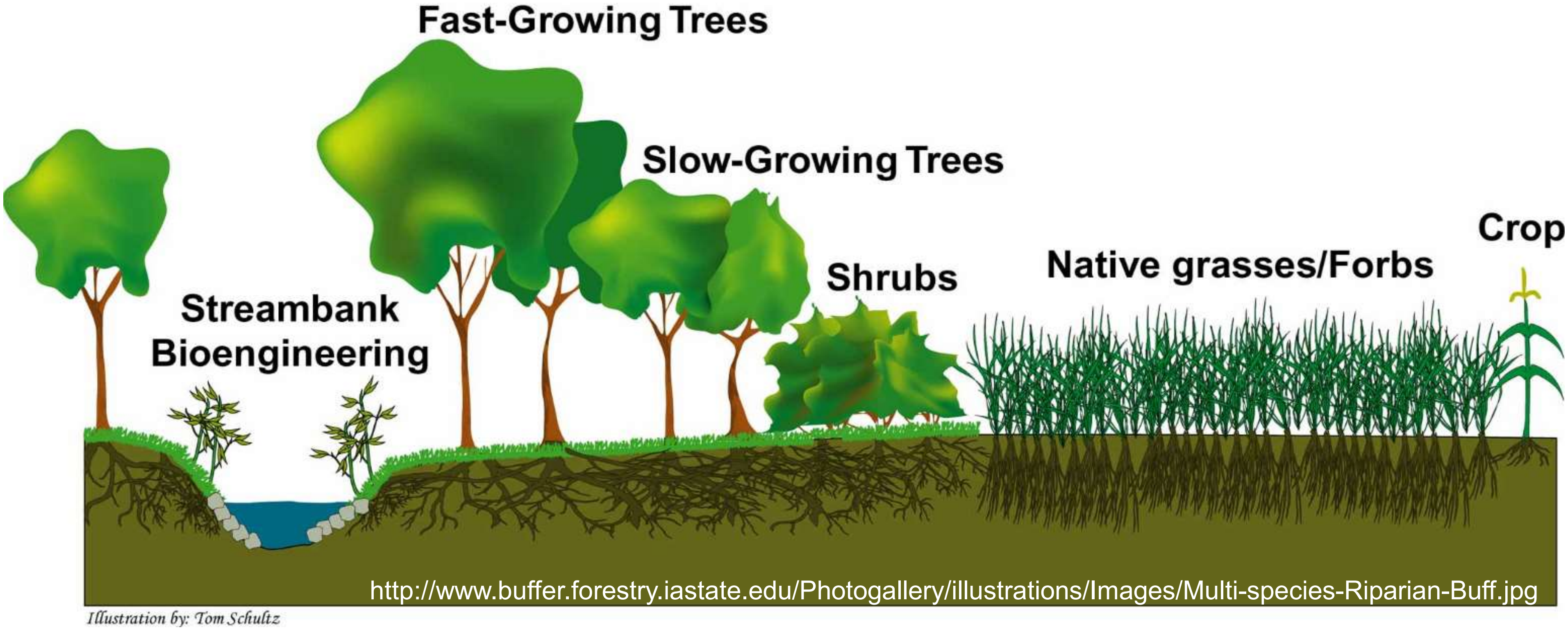
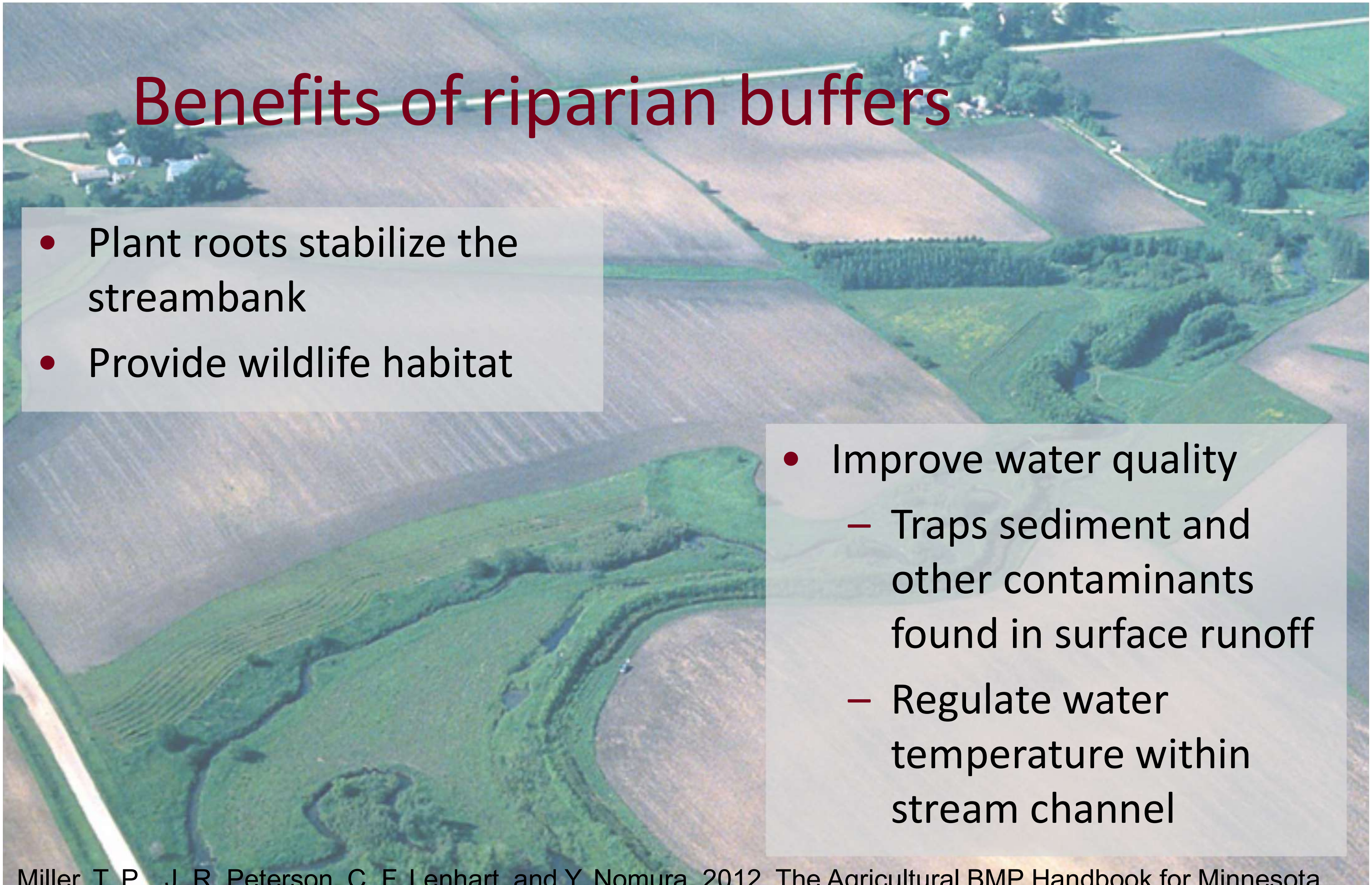
Presentation Overview

1. Riparian Buffers
   - Why we use them
   - How they remove nitrate
2. Saturated Buffers
   - What are they?
   - How do they work?
3. Site Selection
4. Assessing performance
   - How well they work
   - Site conditions impacting performance
5. Future Work
   - Ongoing research
   - Future research needs

What is a riparian buffer?





Benefits of riparian buffers

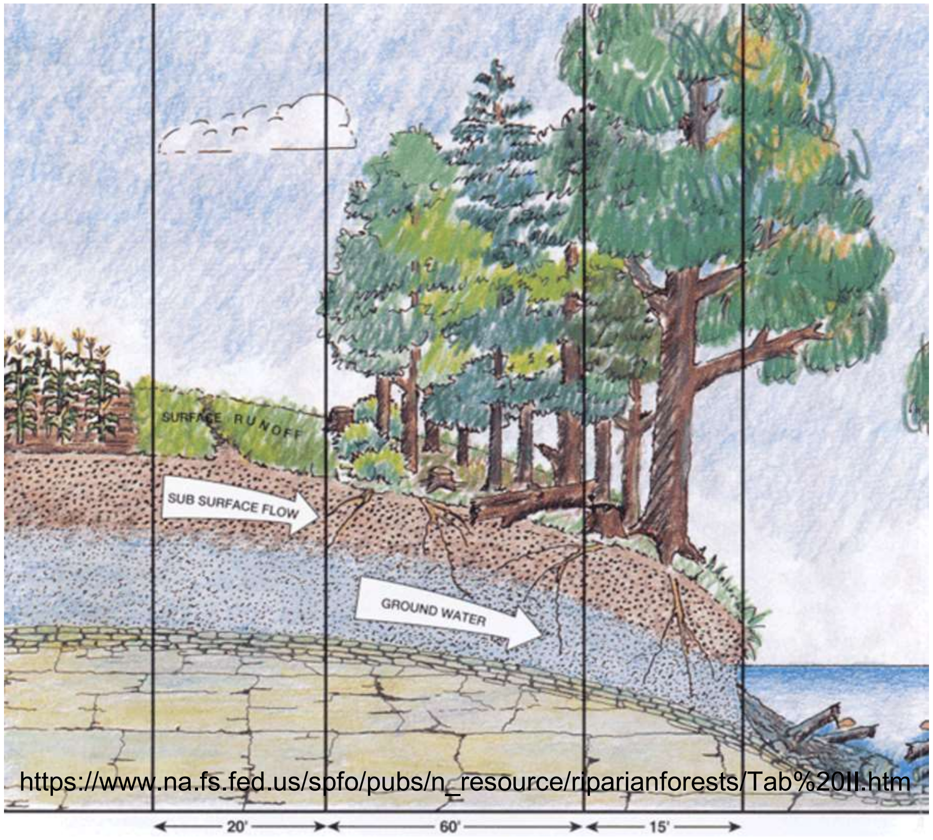
- Plant roots stabilize the streambank
- Provide wildlife habitat

- Improve water quality
  - Traps sediment and other contaminants found in surface runoff
  - Regulate water temperature within stream channel

Miller, T. P. , J. R. Peterson, C. F. Lenhart, and Y. Nomura. 2012. The Agricultural BMP Handbook for Minnesota.

Buffers remove nitrate in subsurface flow

- Nitrate removed mainly through denitrification
  - 38% to 100% removal observed
  - High water table
  - Alternating anaerobic and aerobic periods
  - Healthy population of denitrifying bacteria
  - Sufficient soil carbon
- Vegetation plays minor role



Hefting, M, et al. (2005). Klapproth, J., Johnson, J. (2009).

Traditional drainage systems bypass the riparian buffer and discharge directly to the stream

Can the drainage system and riparian buffer be hydrologically reconnected for improving water quality?

Quiz Time!!!

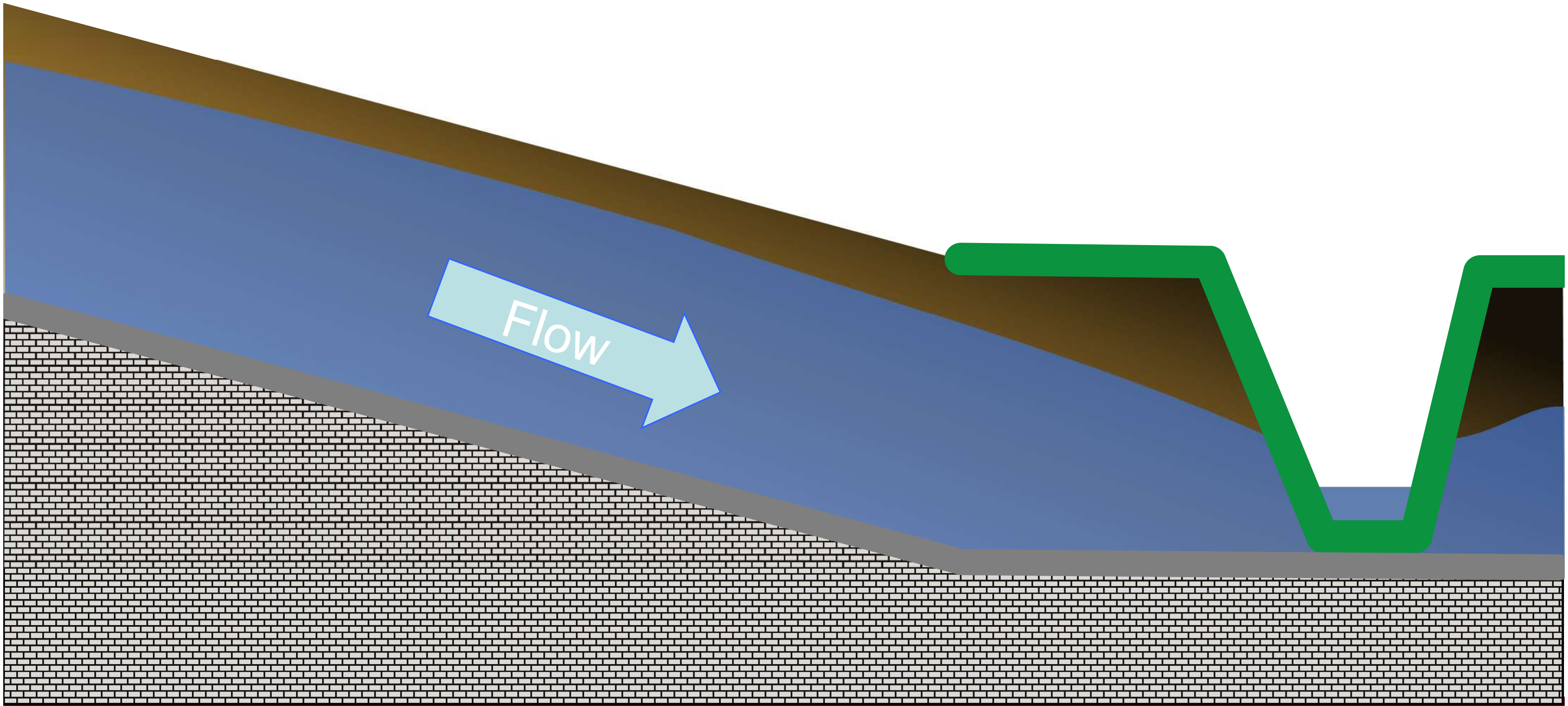
- What conditions are required for a buffer to remove nitrate in a buffer?
  1. High water table
  2. Alternating aerobic/anaerobic (i.e. wet/dry) conditions
  3. Healthy population of denitrifying bacteria
  4. Sufficient soil carbon (>0.75%)

Saturated Buffers

What are they?

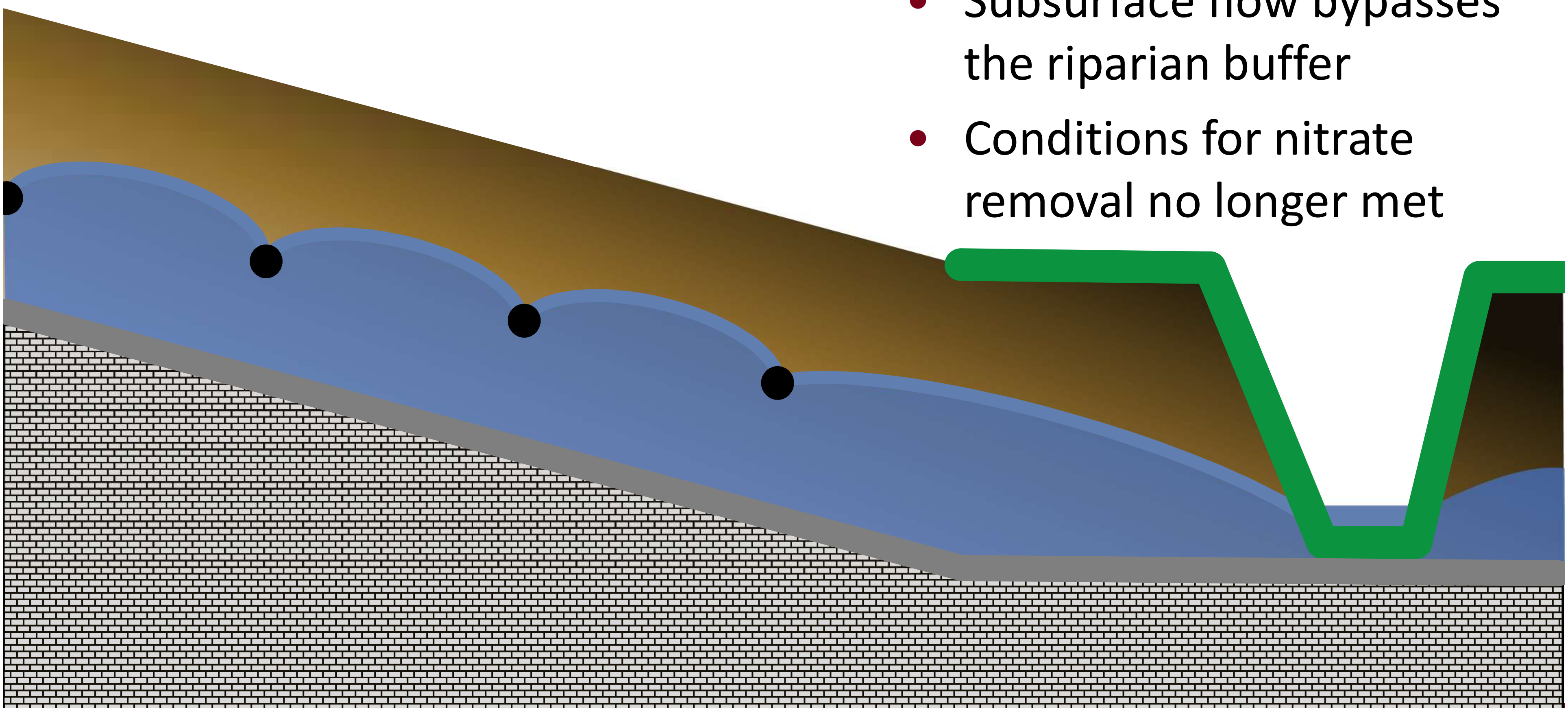
Saturated Buffers – They look the same to me…

No tile drainage in the field – a "natural" system



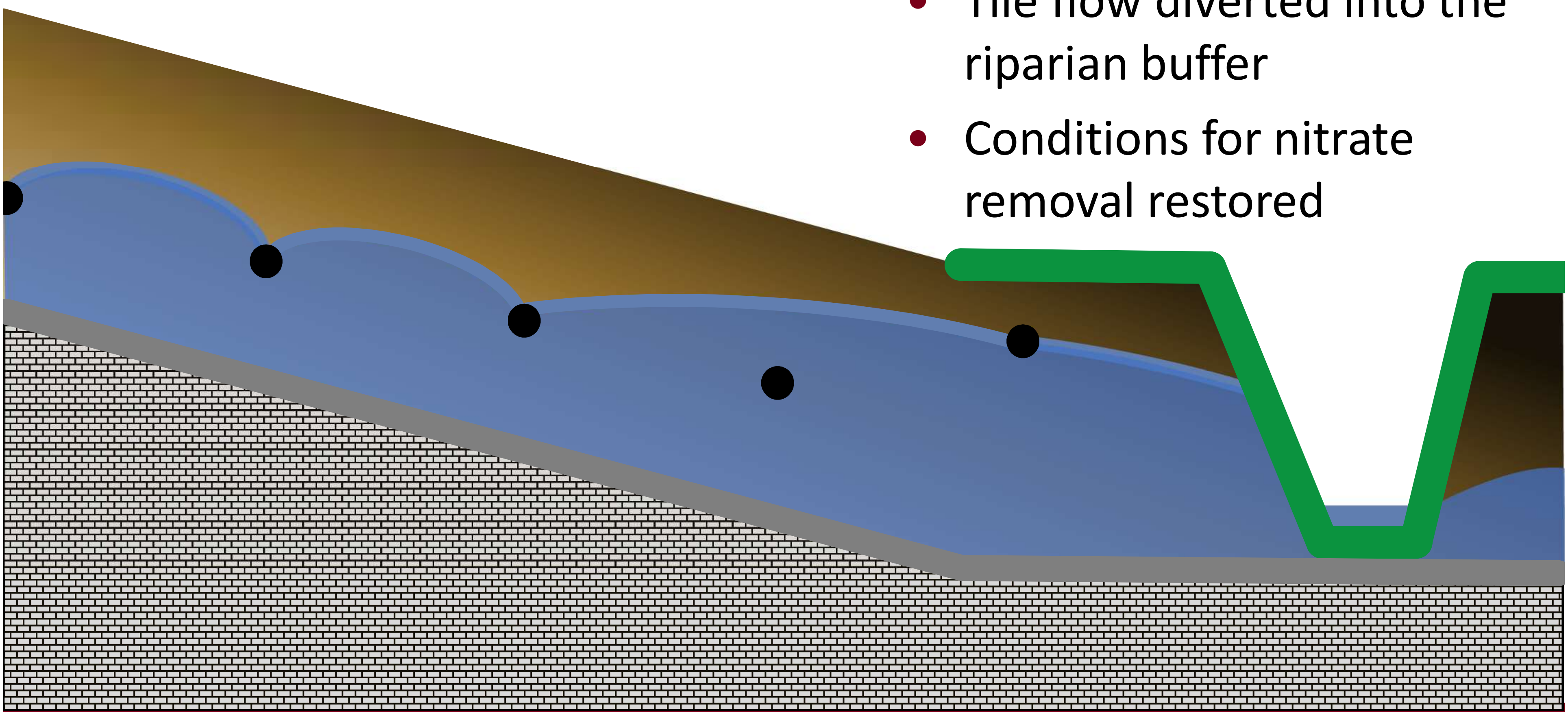
In-field drainage alters the buffer hydrology

- Subsurface flow bypasses the riparian buffer
- Conditions for nitrate removal no longer met

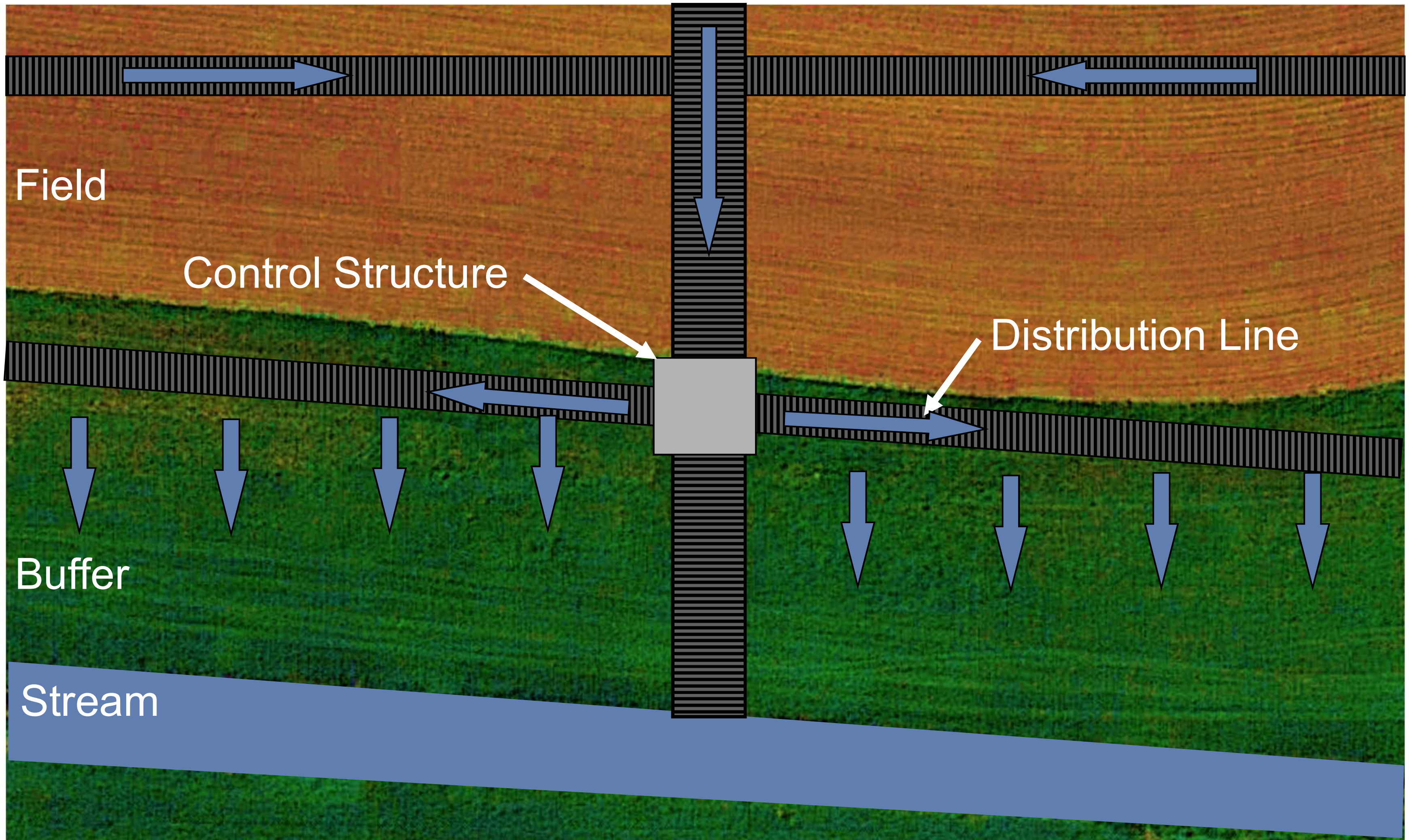


Saturated Buffers mimic "natural" buffer hydrology

- Tile flow diverted into the riparian buffer
- Conditions for nitrate removal restored



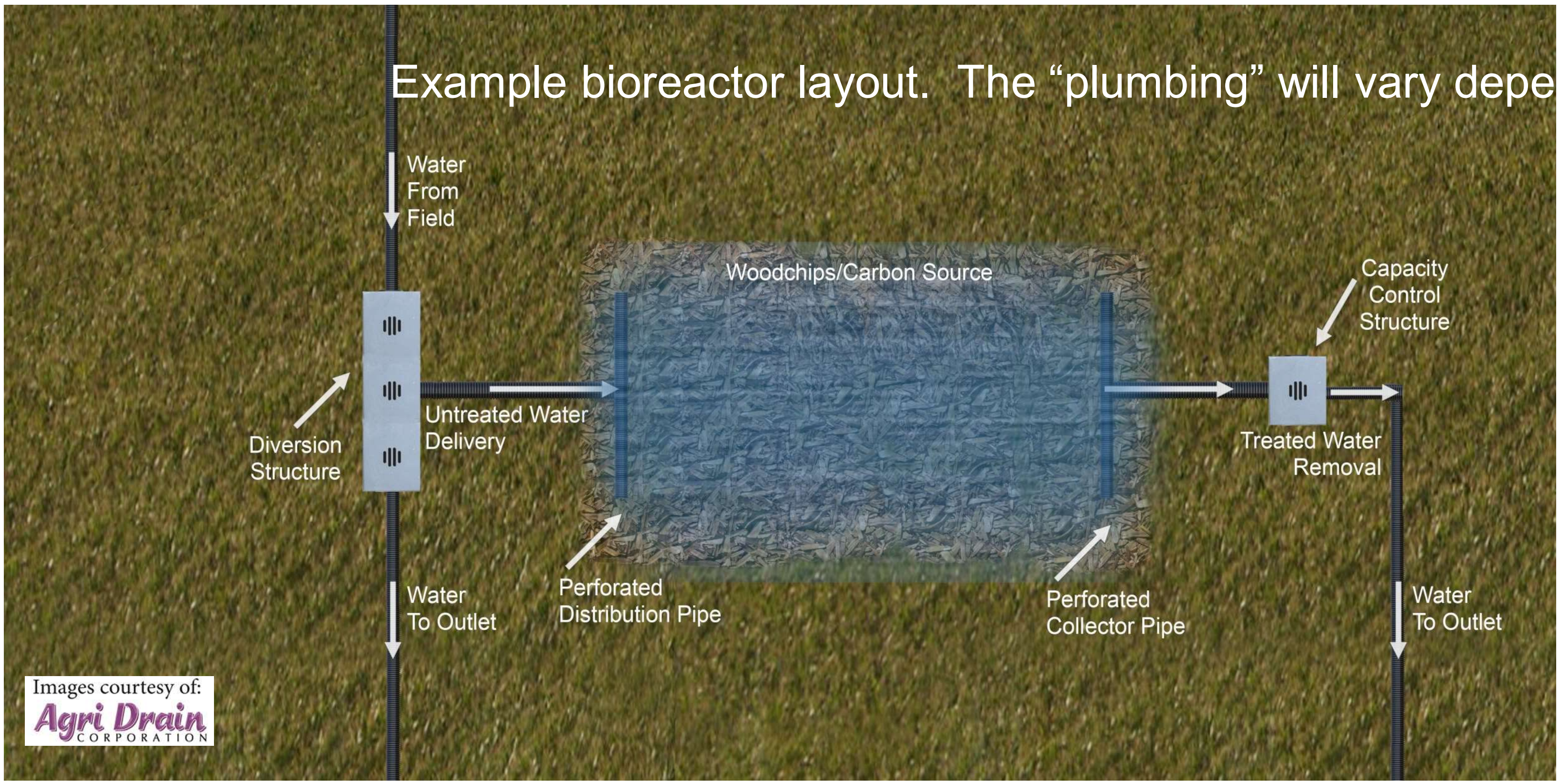
A Saturated Buffer diverts drainage water into buffer



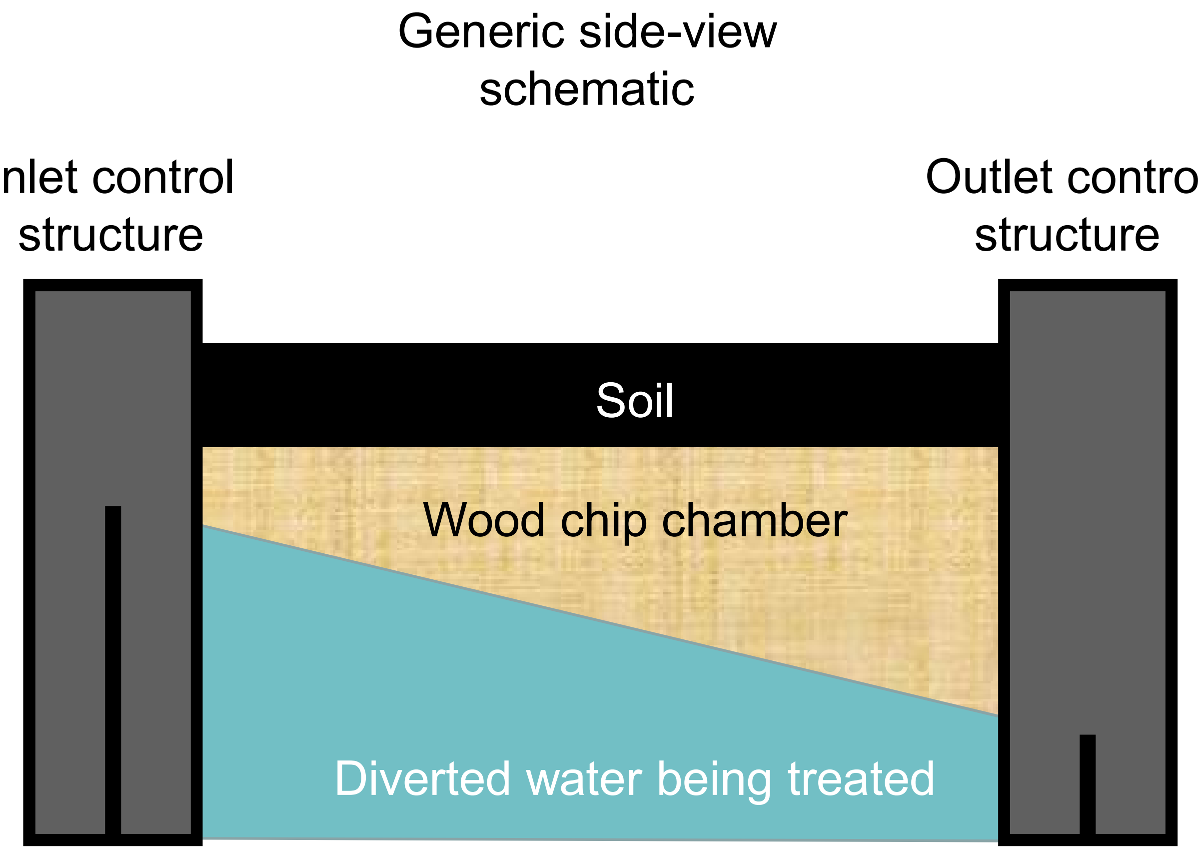
Saturated Buffers

How do they work?

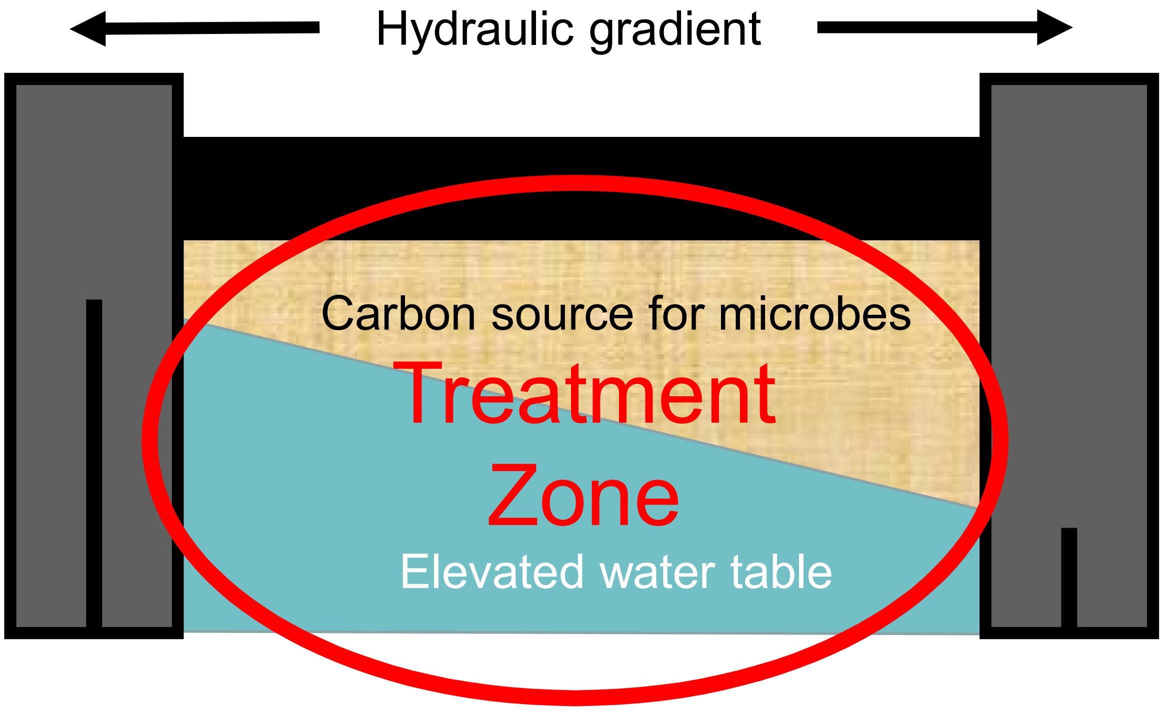
First, let's look at a bioreactor



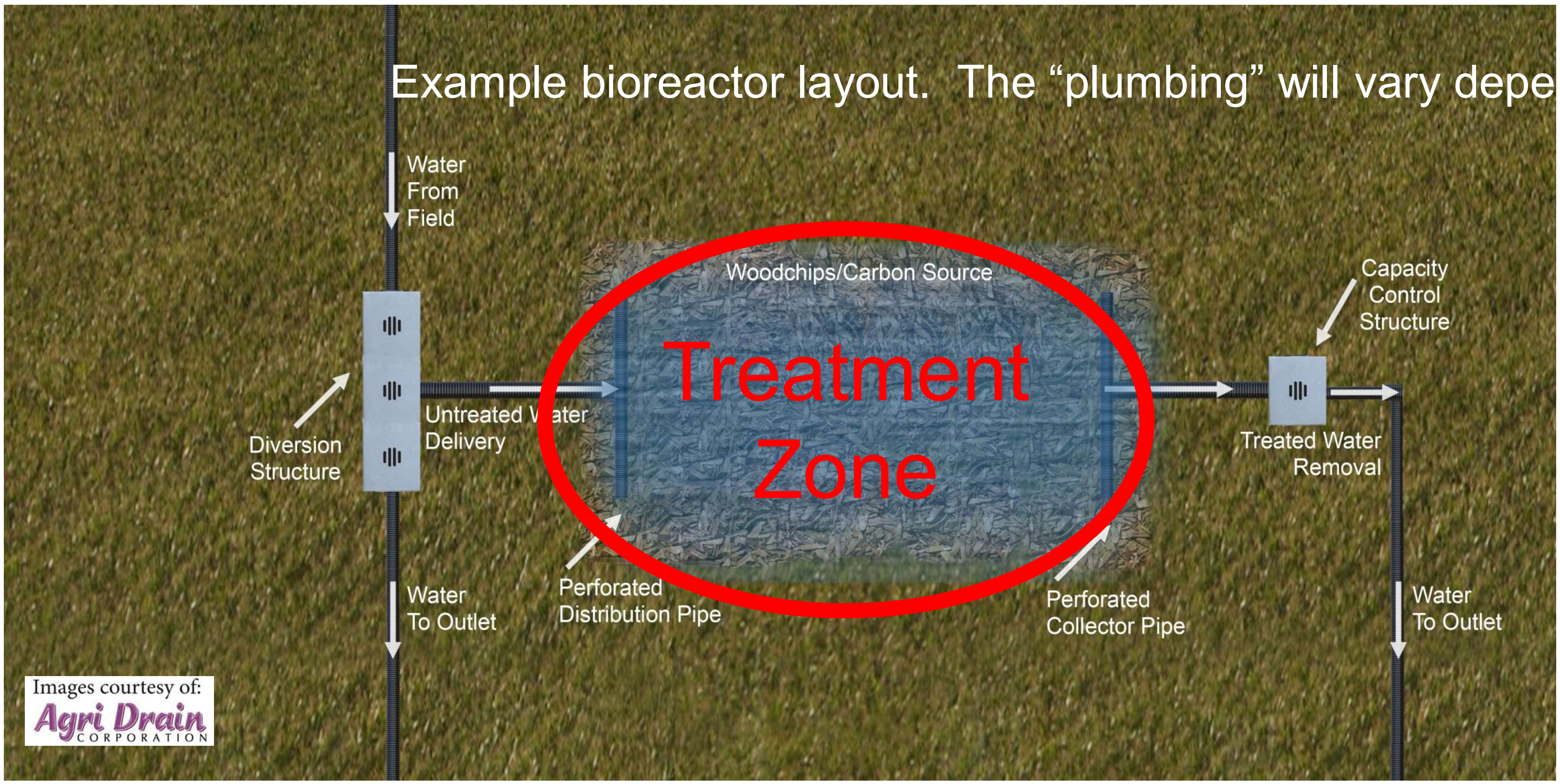
Water movement in a bioreactor



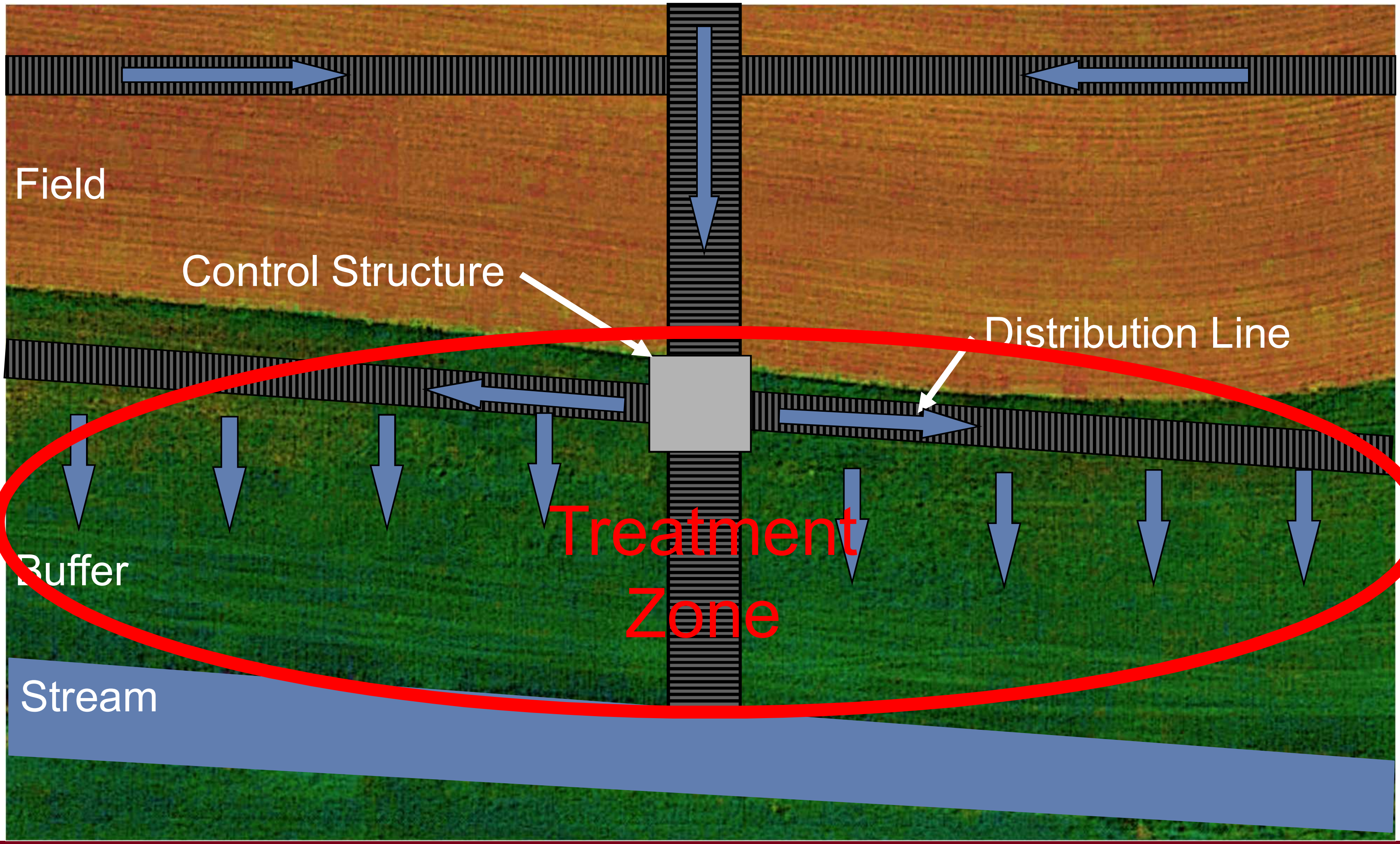
Water movement in a bioreactor



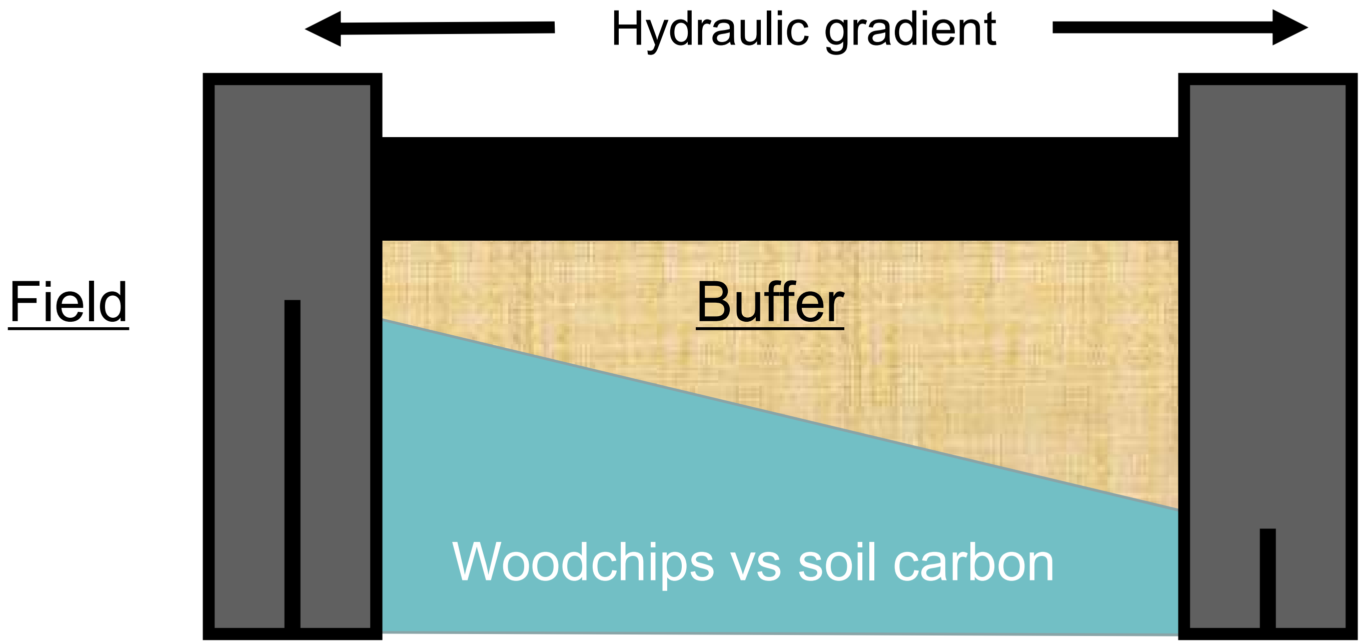
Bioreactor treatment zone



Saturated buffer treatment zone



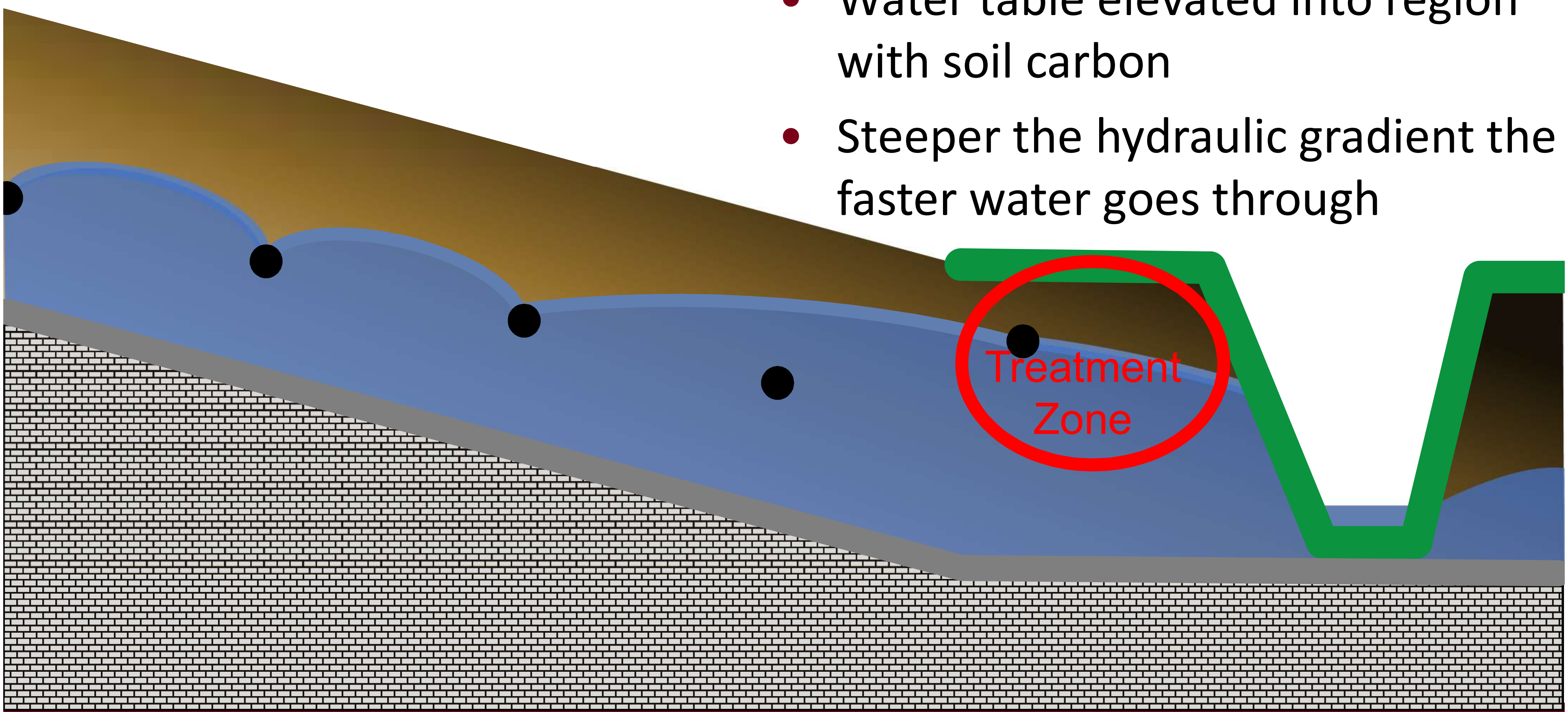
Saturated buffers basically work the same way as a bioreactor



The water level in the ditch functions similar to stop log setting in the outlet structure.

Creating denitrification conditions

- Water table elevated into region with soil carbon
- Steeper the hydraulic gradient the faster water goes through



Key criteria for a Saturated Buffer

1. Tile system to intercept
2. Established vegetated buffer
3. Correct soil conditions
   a) Able to maintain an elevated water table
   b) Soil organic carbon >0.75%
4. Control structure and distribution line
5. Hydraulic gradient across the buffer

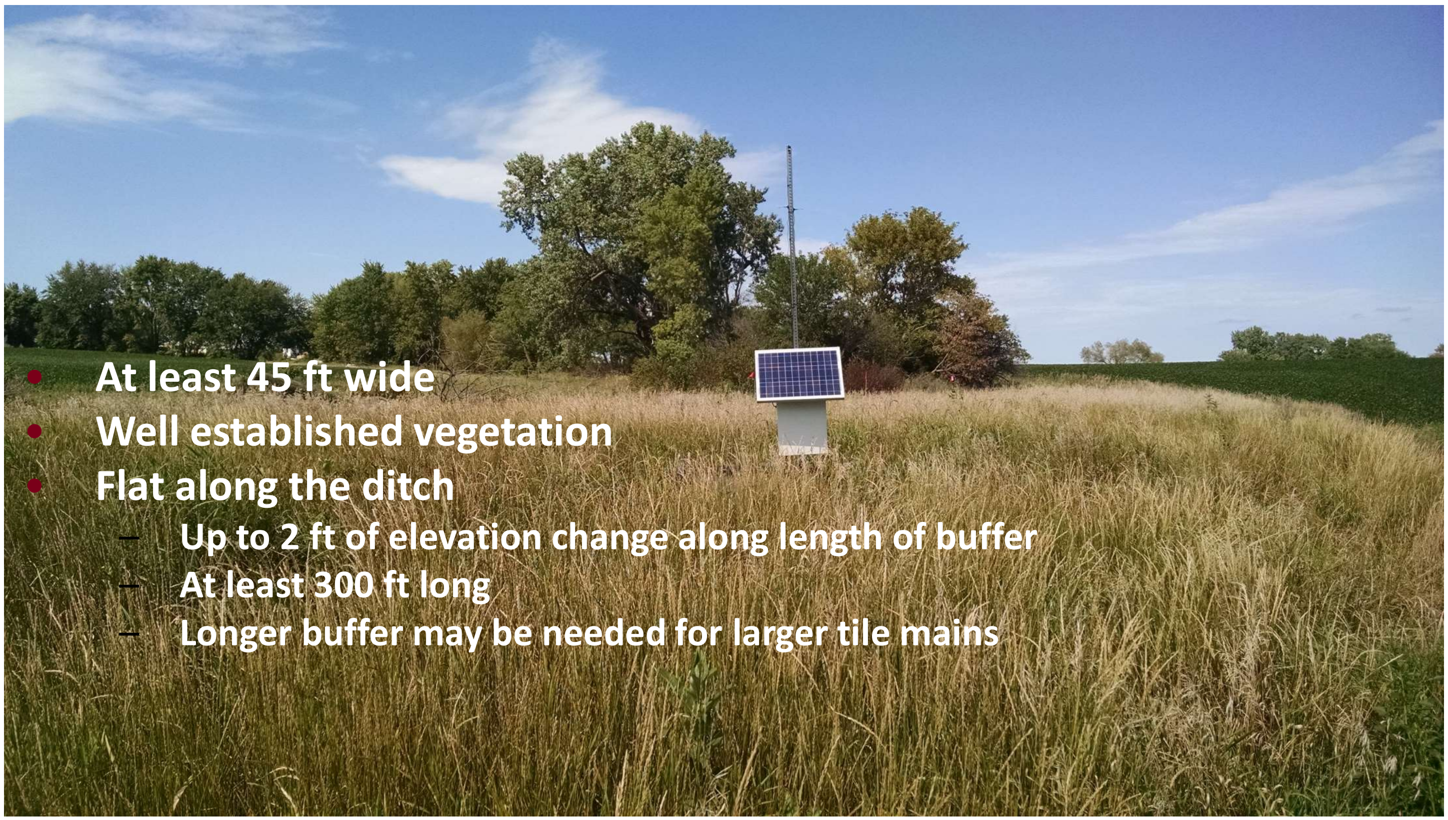
Considerations when selecting a site

Soil Conditions

- Soil must allow you to maintain a high water table
  - Is there a restrictive layer?
  - Will you be able to raise the water into the soil horizons with sufficient organic matter?

- Avoid sand/gravel lens
  - Will the water move too fast to be treated?

Buffer Characteristics

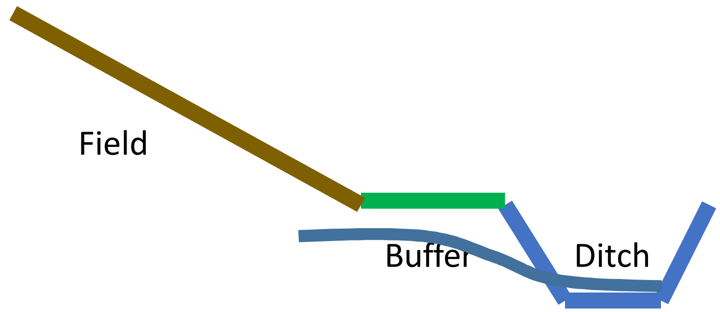


- At least 45 ft wide
- Well established vegetation
- Flat along the ditch
  - Up to 2 ft of elevation change along length of buffer
  - At least 300 ft long
  - Longer buffer may be needed for larger tile mains

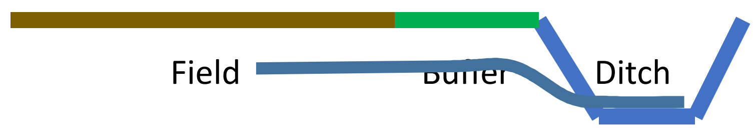
Other Considerations

- Non-perforated main through buffer
  - Minimize the ability for water from the distribution line to short-circuit back into the regular outlet
- Avoid surface inlets
  - You don’t want debris plugging the distribution line

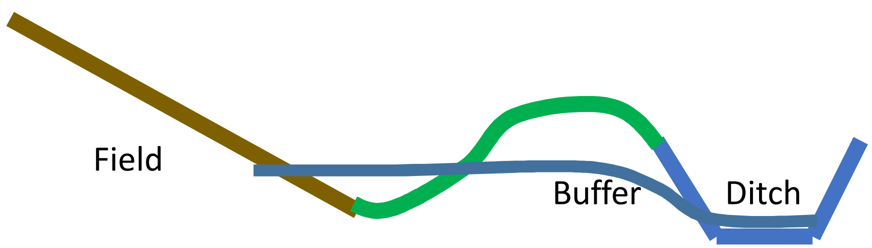
Field Topography – Three Scenarios



The buffer can often be managed at optimum settings throughout the year with no need to manage the control structure.

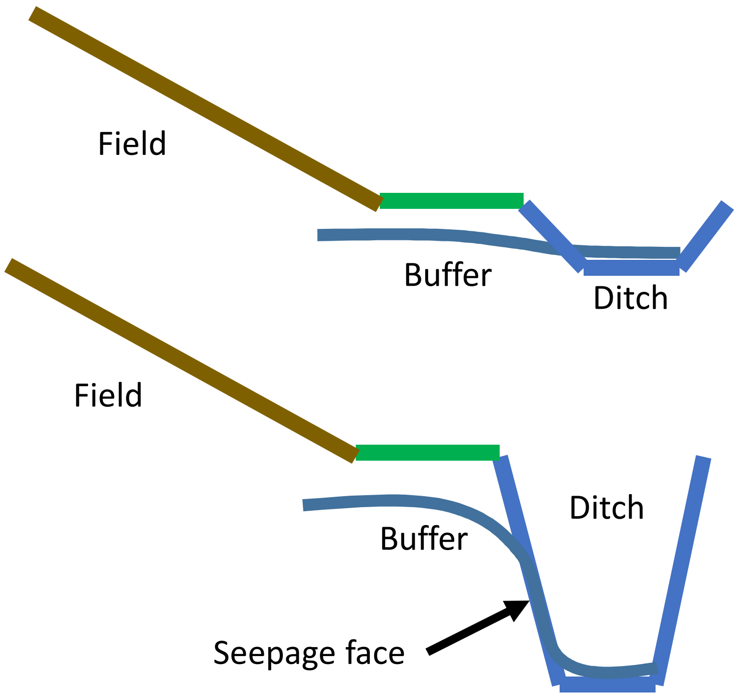


The control structure will need to be managed similar to DWM, which may reduce the volume of water that can be treated.



The site may not be suitable if you are unable to raise the buffer's water table into the organic-rich soil layers without negatively impacting crop production.

Another Consideration – Ditch Depth



A shallow ditch may not have sufficient hydraulic gradient

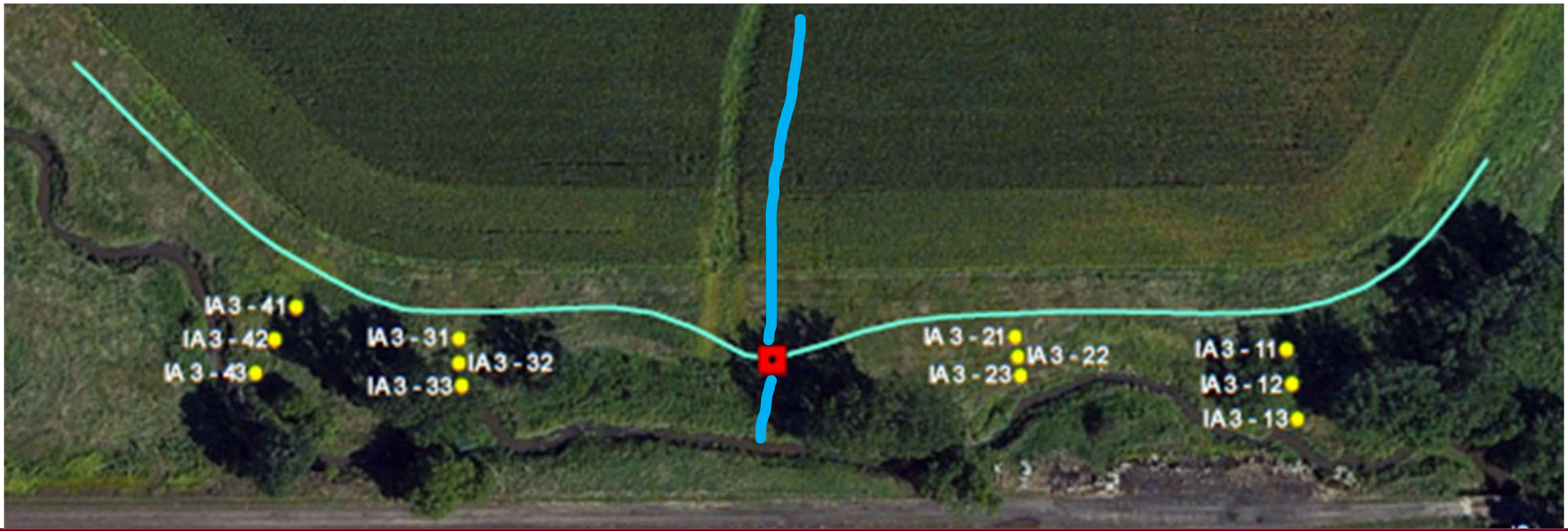
The creation of a seepage face on the ditch bank can reduce bank stability, which can results in maintenance and other environmental issues.

Be especially cautious on sites with sandy sublayers and banks that already show a susceptibility to sloughing.

Assessing Performance

General monitoring layout

- Existing subsurface drainage system intercepted
- Diversion structure and distribution line installed
- Flow from field and bypass flow are measured
- Monitoring wells for groundwater sampling



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Saturated Buffer nitrate reductions vary widely

For the 13 functioning saturated buffers:

- 21% to 95% of annual flow diverted
- 7% to 92% annual nitrate load reductions
- 13 to 179 kg-N removed annually

Site characteristics impacting performance: Nitrate removal

- Newly installed buffers did not perform as well
  - Performance may improve once vegetation firmly established
- All sites had >1.0% soil organic matter throughout the top 1.2m
- Most buffers accomplished meaningful reductions partway across
  - Wider buffers are not necessarily better
- Additional explanations for variation in performance remain unclear

Site conditions limiting performance (flow diversion)

- Highly permeable soil layers
  - Failed to elevate the water table
- Lack of tile flow
- “Flashy” tile systems
- Additional tile outlets within the buffer
- Outlet prone to flooding
  - Backflow into the buffer
  - Reduced hydraulic gradient across the buffer

Where to next?

Current research and future needs

Current research

- Ongoing field monitoring, similar to what has been done
- Greenhouse gas emissions
- Computer modeling of modified buffer hydrology
- Determine key site characteristics needed for successful implementation
- Improve design guidelines for practitioners

Future needs

- Determine partition between plant uptake and denitrification
- Explore different vegetation and biomass harvesting patterns on nutrient removal
- Incorporate more complex pipe systems to increase performance
- Investigate use of soil amendments to improve nitrate and phosphorus removal

In summary….

1. Key conditions for nitrate removal
   - Denitrifying microbes
   - >0.75% soil carbon
   - Alternating aerobic/anaerobic (wet/dry) periods
   - High water table
2. Water table must be elevated in the into the “treatment zone”
3. Hydraulic gradient
   - Where is the water going?

Questions?