Saturated Buffers

EF-02

Figure 1. A riparian zone parallel to the field edge along a creek channel (Manitoba Agriculture).

What do saturated buffers accomplish?

The objective of a saturated buffer is ***Improving Water Quality.*** Saturated buffers are designed to remove nitrates from a portion of the tile drainage water before it is discharged to surface water. They may also decrease the volume of tile water discharged to surface water. Saturated buffers are best considered where the tile main outlet crosses a wide, gently sloping riparian zone (e.g. Figure 1).

Leading US researchers (Christianon et al., 2016) consider saturated buffers a promising BMP for nitrate removal, warranting more research and development. There are currently no saturated buffers utilized or being studied in Manitoba.

Overview of saturated buffers

A saturated buffer is a natural, below ground, biological treatment system located within the riparian soil at the edge of a tiled field (Figure 2). The riparian soil receives a portion of the tile drainage water before it is discharged to surface water.

Tile water is diverted from the tile main outlet pipe into buried, perforated lateral tile drain pipes placed parallel to the outlet waterway within the riparian soil (Figure 2). A stop log control structure on the main tile pipe controls the height of the water above the seepage lateral tile. Drainage water seeps from the lateral tile drain pipe into the riparian soil and travels towards the waterway. Denitrifying bacteria present in the soil convert nitrates in the water to nitrogen gas. Riparian vegetation also utilizes the tile water and dissolved nitrates. In periods of high flow, tile water can flow over the stop logs, bypassing the riparian buffer, ensuring that field drainage is not impeded.

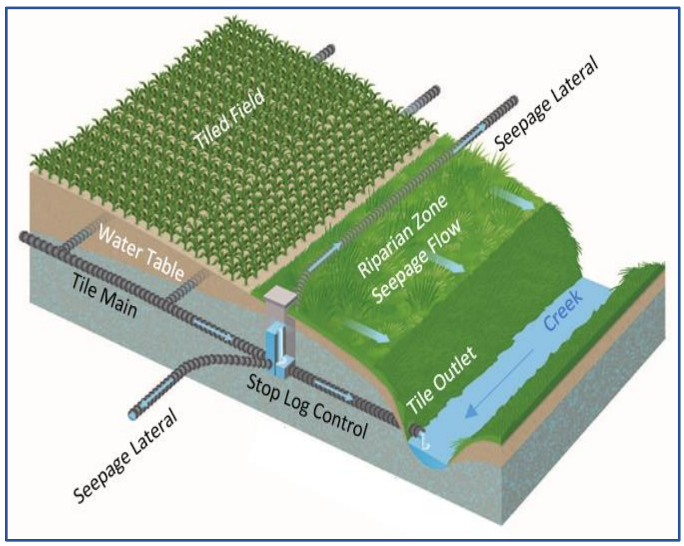

Figure 2. Plan view of saturated buffer, including stop log control structure, seepage lateral and riparian zone parallel to the outlet waterway (source: modified from TransformingDrainage.Org).

Applicability of saturated buffers in Manitoba

The applicability of saturated buffers for Manitoba has not been established. Basic research and demonstration is needed in Manitoba to determine local design criteria and efficacy of this treatment method.

Current research findings on saturated buffers in the United States

Research and demonstration sites were established by the Agricultural Research Service of the USDA in the Bear Creek Watershed of Iowa in 2011 (Figure 3) and at the Maas farm 20 km away in 2013 (Jaynes et. al., 2014). Results from these sites revealed the potential for saturated buffers to remove large quantities of nitrates before tile water enters surface water (Jaynes et. al.,2014):

- 32 to 55% of the tile water was diverted to the saturated buffer at Bear Creek over the years 2011 – 2013 (see also Figure 4, Jaynes et al., ADMC website);
- between 105 and 150 kg of nitrates were removed annually from the diverted water at the Bear Creek site from 2011 to 2013.

Figure 3. Construction of Bear Creek seepage lateral in the riparian zone (Jaynes et al., ADMC website).

Soil types, topography and drainage flows in Iowa are different than in Manitoba. Manitoba drainage flows are low relative to Iowa and would be closer to the lowest flows experienced at the Bear Creek site (i.e. during 2012; Figure 4).

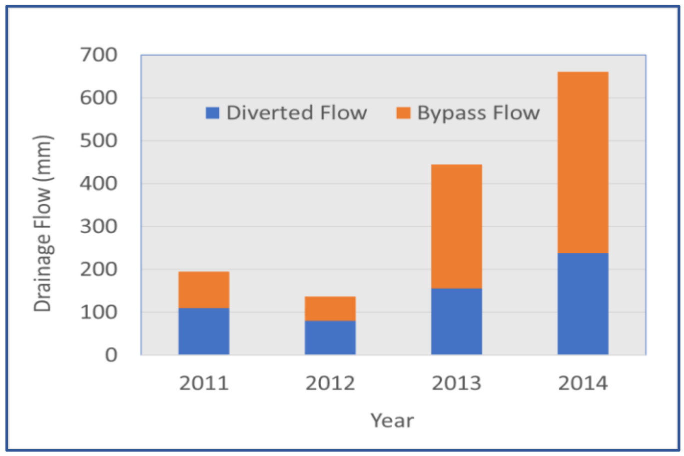

Figure 4. Flow diverted to riparian zone (buffer strip vs flow bypassing riparian zone at Bear Creek (Iowa) (Jaynes et al.; ADMC website).

The Agricultural Drainage Management Coalition (ADMC) established 15 saturated buffer demonstration sites in Minnesota, Iowa, Illinois and Indiana, in 2012 and 2013. Utt et al. (2015) reported large variability in performance of these saturated buffers. Results from 50% of the sites had significant nitrate reduction. The other half either generated insufficient data or did not reduce nitrate. The sites that did not reduce nitrates were largely attributed to poor site selection and design. Design issues impacting performance included the presence of coarse soils, insufficient organic matter and insufficient hydraulic gradient in the riparian zone toward the creek. Utt et al. (2015) recommended that site investigations and design procedures be standardized.

Jayne et al. (ADMC website) reported some reduction of dissolved phosphorus in tile water after passing through the riparian zone. However, Utt et al. (2015) concluded that the saturated buffers tested did not remove dissolved phosphorus from the tile water. Additional research may be warranted to asses this question, where dissolved phosphorus is an issue for tile water quality.

What are some design considerations?

Criteria for selecting a research site and designing a saturated buffer should take into account soil properties, topography, vegetation type, flow rates, drainage intensity, water temperature and nutrient concentration in current tile flows. Saturated buffers are best designed to treat only a portion of the peak tile flow, to keep them cost effective.

USDA-NRCS (2016) suggests treating as much of the peak flow as possible, with a minimum of 5%, depending on the available riparian zone, field size and drainage intensity. The USDA-NRCS (2016) requires a minimum of 1.2 percent organic matter in the top 2.5 ft (0.76 m) of the soil in the riparian zone and a minimum width of riparian zone of 30 ft (9.1 m). Sites with highly permeable soils (i.e. sands and gravels) have been found to be unsuitable for this practice (Utt et al., 2015). Creek bank stability under saturated conditions must be evaluated.

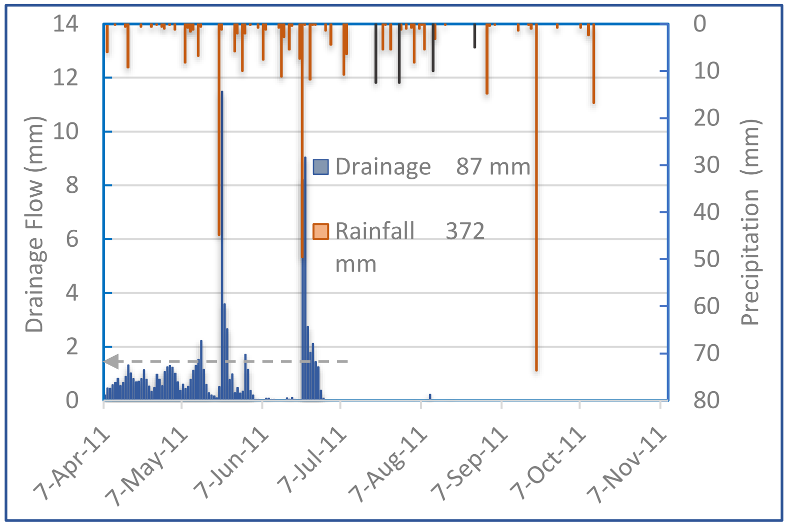

Figure 5. Drainage flow vs. precipitation for Hespler Farms research plot (Cordeiro, 2013); arrow represents 1.6 mm/day maximum treatment rate.

Where possible, design of a saturated buffer should consider locally-measured data. Illustrative local flow drainage flow and precipitation are provided in Figure 5. In this example, a saturated buffer designed for 0.06 in/day (1.6 mm/day) seepage rate (see arrow) would treat water below the arrow; whereas drainage flow above 0.06 in/day (1.6 mm/day) would bypass the treatment system and flow directly to the creek.

In monitoring the performance of a saturated buffer, hydrological variables that should be measured include water table levels and gradients, vertical and lateral seepage rates (i.e. hydraulic conductivity), flood frequency of the riparian zone, and ditch or creek depth. Quantification of nitrate and phosphorus removal is essential, which can be supported through measuring the percent of flow diverted.

Outstanding questions and potential future improvements

Saturated buffers are a developing technology. Optimizing design and performance of this BMP for Manitoba conditions, particularly climate and topography, will require the following:

- Basic research and demonstration projects to validate the feasibility of the practice and to refine design, operation and performance monitoring protocols.
- Standardized site selection criteria to avoid failures that have been observed elsewhere. Criteria are needed for soil texture, organic matter and stratigraphy, in addition to topography, hydraulic gradients, riparian width and stream flow characteristics.
- Performance criteria for dissolved phosphorus and nitrate removal.
- Protocols for the management of the saturated buffer including vegetation harvest to facilitate phosphorus removal.
- Cost-benefit analysis for various scenarios. This analysis will be site-specific and depend on the percentage of flow to be treated, seepage path travel time, riparian area properties, size of the crop area being drained and drainage intensity.

Complementary practices

Saturated Buffers are complementary to other BMPs that reduce nutrients in tile outflow or drainage volume:

- *IF-01 – Nutrient Management;*
- *IF-02 – Cover Crops;*
- *IF-03 – Controlled Tile Drainage.*

Saturated Buffers can work as an alternative to other tile water treatment or reuse practices:

- *WS-01 – Tile Water Recycling,* recycles both water and nutrients but is more expensive than saturated buffers;
- *WS-02 – Constructed Wetlands,* one wetland can treat multiple tile outlets as an alternative to saturated buffers;
- *EF-01 – Bioreactors,* which may be more expensive than saturated buffers but could be more robust.

Design aids

USDA – NRCS, 2016. Conservation Practice Design Standard – Saturated Buffer Code 604: accessed at USDA – NRCS website.

Additional BMP resources

Agricultural Drainage Management Coalition. Saturated Buffers video and presentation on Bear Creek results: access on ADMC website for Saturated Buffer Strips.

Christianson, L.E., J. Frankenberger, C. Hay, M.J. Helmers, and G. Sands, 2016. Ten ways to reduce nitrogen loads from drained cropland in the Midwest. Pub. C1400, University of Illinois Extension.

Illinois Council on Best Management Practices. Saturated Buffers Video Clip: access on Illinois Council on Best Management Practices site.

Jaynes, D. and T. Isenhart. Bear Creek saturated buffer year 4 results: access on ADMC website for Saturated Buffer Strips.

Transforming Drainage Website. Managing water for tomorrow's agriculture: access website through Transforming Drainage Organization.

References

Cordeiro, M. R. C., 2013. Agronomic and environmental impacts of corn production under different water management strategies in the Canadian Prairies. PhD Thesis. Department of Biosystems Engineering, University of Manitoba.

Jaynes, Dan B., T. M. Isenhart, and T. B. Parkin, 2014. Reconnectin riparian buffers with tile drainage (2). Leopold Center Completed Grant Reports. 463; access on Iowa State University Digital Registry.

Utt, N., D. Jaynes, and J. Albertsen, 2015. Demonstrate and evaluate saturated buffers at field scale to reduce nitrates and phosphorus from subsurface field drainage systems. Project report submitted to the USDA – NRCS (Grant 69-3A-75-11-205) and USDA-FSA (Order AG-64SS-P-12-0051 and AG-3141-P-15-0168).