NATURAL RESOURCES CONSERVATION SERVICE - ILLINOIS

CONSERVATION PRACTICE GUIDANCE

604 – SATURATED BUFFER

I. SCOPE

This guidance provides information and recommendations for planning and design of saturated buffers. A saturated buffer (SB) is a vegetated buffer in which a water table is raised by diverting water from a subsurface drainage system. The raised water table under the buffer enhances denitrification, resulting in reduced nitrate loading to surface water from a subsurface drainage system.

II. SITING RECOMMENDATIONS

At least two conditions are necessary for nitrate removal in a saturated buffer:

- Soil in the buffer must have sufficient carbon content to serve as an energy source for denitrifying bacteria. Conservation Practice Standard (CPS) 604 requires a minimum of 0.75 % organic carbon (1.2% organic matter) be present in the soil to 2.5 feet depth. In the absence of specific soil test information, use the Organic Matter report under Soil Physical Properties in Web Soil Survey.
- The water table needs to be capable of being raised in the buffer to submerge high carbon soil layers, leading to the anaerobic conditions conducive for denitrification. Evidence of a historically high water table at the depth of the high carbon soil layers would demonstrate meeting this criterion. Presence of a hydraulically restricting layer in the buffer soil, enabling raised water table elevations with redirected tile drainage flow would also meet this criterion. If using Web Soil Survey, check the water features report for seasonal high water table and drainage class. The soil should be poorly or somewhat poorly drained or the SB will likely not be able to raise the water table to create saturated conditions near soil surface.

Streambank or ditch bank stability is addressed in CPS 604 by avoiding placement of saturated buffer 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. The planner should avoid placing the distribution pipe along any channel that is subject to active lateral migration, unless measures are installed to prevent excessive geomorphic change to the configuration of the streambank.

III. DESIGN AND EVALUATION

CPS 604 allows for several alternative methods for designing the SB to meet the required criteria. This guidance document includes information about those alternative design and evaluation processes, presented in increasing order of complexity. The main differences in the processes involve the method of determining the capacity of the drainage system. The minimum design flow into the SB is 5% of the maximum capacity of the drainage system.

<u>Determining System Capacity</u>

Option 1: Mainline Configuration

This alternative may be used in cases where there is very limited information about the drainage system; if more information is available, use a different method.

Use Manning's equation to estimate the maximum capacity of the outlet main using an appropriate value of Manning's n. Use the minimum predominant slope along the mainline between the last lateral inlet and the mainline outlet.

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

Where *Q* = Flow, ft^3/second (cfs)

n = Manning's roughness coefficient

A = Cross sectional area of flow, ft^2 ($A = \pi \frac{d^2}{4}$ for round pipe)

R = Hydraulic radius, ft ($R = \frac{d}{4}$ for round pipe)

d = diameter of pipe, ft

S = Slope of pipe, ft/ft

Example: 6" diameter mainline made of corrugated PE. Minimum mainline slope is 0.2% and n = 0.015.

d = 0.5 ft

$A = \pi \frac{0.5^2}{4}$ = 0.196 ft^2

$R = \frac{0.5}{4}$ = 0.125 ft

S = 0.2/100 = 0.002 ft/ft

Resulting system capacity for this example is 0.217 cfs. Design flow for the SB would be 5%, or .011 cfs.

Option 2: Drainage Coefficient

This alternative may be used if a tile map and information on the existing drainage system is available. The definition of the drained area is taken from the lateral spacing recommendations of the soil, as specified in the Illinois Drainage Guide. The outer boundary of the drained area is delineated by a line around the tiled area, at a distance of one-half of the tile lateral spacing recommended in the Drainage Guide.

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

$$Q = \frac{(DC)\ (DA)}{23.8}$$

Where DC = Drainage coefficient, inches/day

DA = Acres drained

Example: *D*C = 3/8 inch per day; 6 acres drained by system.

System capacity for this example is 0.095 cfs. The design flow for the SB would be 5% of the system capacity, or .005 cfs.

If a complete drainage tile map does not exist, it is possible to estimate the contributing acres of tile drainage (DA), especially in cases where the landscape is characterized by a predominance of tile drainage. This estimation process assumes that all of the watershed acres with soil drainage group A (poorly drained) are either already drained or will be in the near future, plus half of the watershed acres in soil drainage group B (somewhat poorly drained). To use this estimation method:

- Delineate the surface drainage area of the point where the SB is proposed.
- Create a list of the soils in the delineated area, along with the acres of each soil type and their drainage group.
- Estimated *DA* = sum of the acres of poorly drained soils plus half of the acres of somewhat poorly drained soils.

Option 3: Modeling Techniques

Drainage models such as DRAINMOD may be used to estimate flow into and through the saturated buffer. If a model of the system is created, drain flows by day, month and year may be obtained. The system capacity can be taken to be the maximum flow experienced during the simulation period, or the value with 1% probability of exceedance. A minimum simulation period of 15 years is recommended.

Sizing Distribution Pipe

The saturated buffer does its work by directing at least 5% of the system flow capacity to the distribution pipe. Flow in the distribution pipe is to be governed by the soil properties and the hydraulic gradient across the width of the buffer. Ensure that the capacity of the distribution pipe is larger than the available infiltration rate of the soil, so that the distribution pipe is not the limiting factor for SB flow.

Collect survey data adequate to plot a profile along the location of the proposed distribution pipe (parallel to the buffer), with several cross sections along that line. Each cross section should show elevation of water surface in the receiving channel (drainage ditch), the slope of the bank and buffer, and the distance from the distribution pipe to the edge of the receiving channel.

Use Web Soil Survey to check the water features report for seasonal high water table and drainage class. The drainage class should be poorly or somewhat poorly drained or the SB will not likely be able to raise the water table and create saturated conditions near the soil surface.

Determine the saturated hydraulic conductivity of the soil through which the distribution pipe will send flow (K_{sat}). If using Web Soil Survey, find this in Soil Data Explorer

→ Soil Properties and Qualities →Soil Physical Properties →Saturated Hydraulic Conductivity.

Use the weighted average of all layers, if the impervious layer is deeper than the profile in Web Soil Survey. If the impervious layer is identified in Web Soil Survey, use the weighted average of the soils above that depth.

At minimum, confirm this information through examination during the required onsite geological investigation. The investigation will preferably include Guelph permeameter measurements which would preclude the need to analyze K_{sat} using the soil survey data.

The horizontal distance from the distribution pipe to the receiving channel (L) is used with the Dupuit-Forchheimer assumptions (Skaggs, 2015) to estimate the flow from the distribution pipe, per unit of length (q, ft^3/hr per foot):

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

Figure the hydraulic head at the flash board setting of the water control structure (h_1) and the head at the outlet of the saturated buffer (h_2, base flow in the receiving channel) relative to the impervious layer in the soil. Set h_1 to maintain a water table within 12 inches of the ground surface at the location of the intersection of the distribution pipe with the main line.

For preliminary estimations prior to the geologic investigation, depth to impervious layer can sometimes be estimated from soil survey data. An impervious layer may be assumed if Web Soil Survey shows a K_{sat} value in the soil profile that is an order of magnitude lower than the layer above it. When there is no apparent impervious layer in the site data, it is common to estimate the depth to impervious layer to be 10 feet below the ground surface at the location of the proposed water control structure.

Compute the minimum length of distribution pipe (l, in feet) by dividing the required design flow rate by the unit flow from the pipe, with appropriate units:

$$l = \frac{3600\,Q}{q}$$

Note that this sizing method requires the designer to ensure several key features of the saturated buffer. If either of these is not possible, divide the analysis into multiple reaches to determine SB flow and distribution pipe length:

- Keep the distance *L* from the distribution pipe to the outlet channel relatively constant (within ± 10%) throughout the SB length.
- Maintain the elevation difference (hydraulic head) between the distribution pipe to the receiving channel relatively constant throughout the SB length. This may require additional water control structures along the length of the distribution pipe. CPS 604 allows a maximum elevation difference between structures of 3 feet.

Spreadsheet Design Tool

A spreadsheet tool has been developed to help automate some of the computations described in this section. The most recent version of the spreadsheet tool may be obtained on the Illinois NRCS engineering website at https://www.nrcs.usda.gov/wps/portal/nrcs/main/il/technical/engineering/.

Bank Stability Analysis

Introducing a distribution pipe along a stream or ditch bank can potentially affect the soil characteristics, especially cohesion. Preferably, the SB will be located where the receiving channel is not incised; recommend a different conservation solution for those sites. However, if the location along an incised channel is unavoidable, perform a slope stability analysis to demonstrate an acceptable level of safety against saturated streambank failure.

Visual observation for bank stability and lateral migration potential is the first step. Take photographs of the area to document stability, and collect aerial maps of the stream channel to document that the stream channel is likely to remain in the same place over time.

Refer to the National Engineering Handbook (NEH) 654, Technical Supplement 14A for guidance on stable saturated bank slopes with different soil types. If the banks on site are less steep than the slopes in the NEH guidelines, bank stability for the SB may be assumed as long as the visual evidence is positive.

There are many valid geotechnical methods for analyzing slope stability; these are beyond the scope of this guidance document.

If there are observed bank stability problems on site during the planning phase, or if the proposed condition is predicted to introduce bank stability problems, refer to CPS 580

Streambank and Shoreline Protection to plan protective measures for the conservation system.

REFERENCES

Skaggs, W. Personal Communication 6/30/2015.

USDA – Natural Resources Conservation Service, Illinois. September, 2012. Conservation Practice Standard 580 – Streambank and Shoreline Protection.

USDA – Natural Resources Conservation Service, Illinois. April, 2017. Conservation Practice Standard 604 – Saturated Buffer.

USDA – Natural Resources Conservation Service. National Engineering Handbook, Part 650 Engineering Field Handbook, Chapter 3 Hydraulics.

USDA – Natural Resources Conservation Service. National Engineering Handbook, Part 650 Engineering Field Handbook, Chapter 19 Hydrology Tools for Wetland Identification and Analysis.

USDA – Natural Resources Conservation Service. National Engineering Handbook, Part 654 Stream Restoration Design, Technical Supplement 14A Soil Properties and Special Geotechnical Problems Related to Stream Stabilization Projects.