Frequency of Concentrated Flow Through Agricultural Riparian Buffers in the Virginia Coastal Plain and Piedmont

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Introduction

The health of the Chesapeake Bay has declined in recent years due to nutrient-induced eutrophication (Boesch et al., 2001). Agricultural runoff contributes a large fraction of the nutrient load: ~20% of the N, ~40% of the P, and ~40 of the sediment delivered to the Chesapeake (Powell and Kotula, 2012). Agricultural forested riparian buffers are intended to reduce sediment and nutrient runoff from agricultural fields adjacent to Bay tributaries (Figure 1 & 2). To be effective, field runoff should be widely disseminated within buffers, allowing long water residence time in the buffer. However, effectiveness is reduced when field topography concentrates runoff in topographic lows, potentially leading to channelization and rapid water movement through the buffer (e.g., Dosskey et al., 2002; Tomer et al., 2009).

Our field observations suggest that flow concentration may be widespread on agricultural fields in the Virginia Coastal Plain and Piedmont, potentially reducing buffer effectiveness significantly. We use GIS to determine the extent of flow concentration in buffers within the Virginia Coastal Plain and Piedmont in the Chesapeake Bay watershed. We seek to answer the following questions:

1. What fraction of agricultural drainage exits into buffers at points of concentrated flow?
2. Does concentrated flow produce channels that bypass buffers?

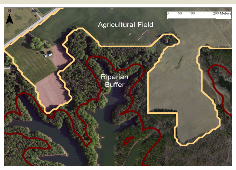


Figure 1. Aerial imagery of a 100 foot riparian buffer bordering an agricultural field in James City County, Virginia.

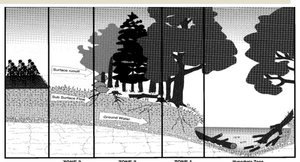


Figure 2. Representation of a three-zoned riparian buffer. Inputs into the stream are highlighted with arrows denoting surface runoff, subsurface flow, and groundwater (from Lowrance et al., 1997).

Study Area

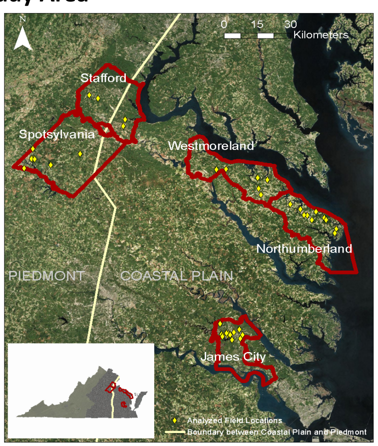
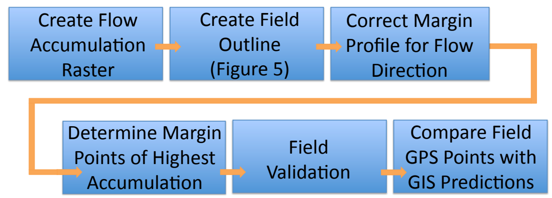


Figure 3. Map of field locations in five counties throughout the Coastal Plain and Piedmont, with an inset map of the state of Virginia.

Methods: GIS Analysis of Field Runoff



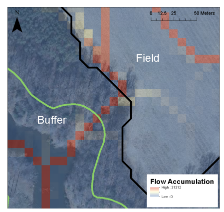


Figure 4. Example of a discrete location on a field in James City County with a high flow accumulation (red pixels) exiting the agricultural field and entering directly into the riparian buffer.

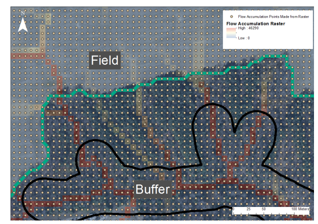


Figure 5. Field outline in James City County snapped to flow accumulation points. The flow accumulation raster and aerial imagery were used to create the field outline.

Methods: Field Identification of Channels and Concentrated Flow

We walked the field margin adjacent to riparian buffers searching for evidence of concentrated flow, such as sediment erosion, standing plant movement, unidirectional debris movement, and channel incision. Locations of channelization and concentrated flow were recorded with a GPS point for comparison to flow accumulation calculated in GIS.

Figure 6. Examples of channels mapped within riparian buffers adjacent to agricultural fields in James City County. Observed channels were as deep as three meters and as wide as five meters.

Results

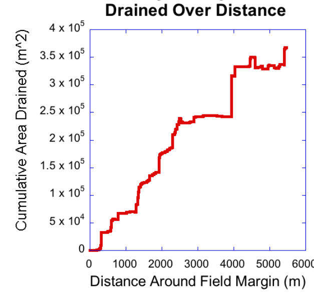


Figure 7. Graph showing the cumulative area drained around the entire field margin. Spikes on the graph display points on the margin with high flow accumulation.

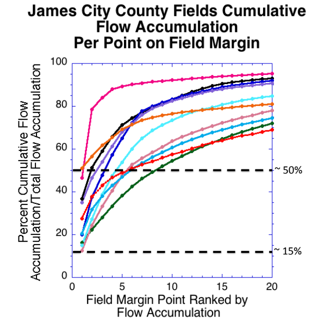


Figure 8. Graph depicting percent of flow accumulation per point along the defined field margin. All fields studied exhibited a logarithmic pattern, meaning that there is concentrated high flow at a few discrete points along the field margin.

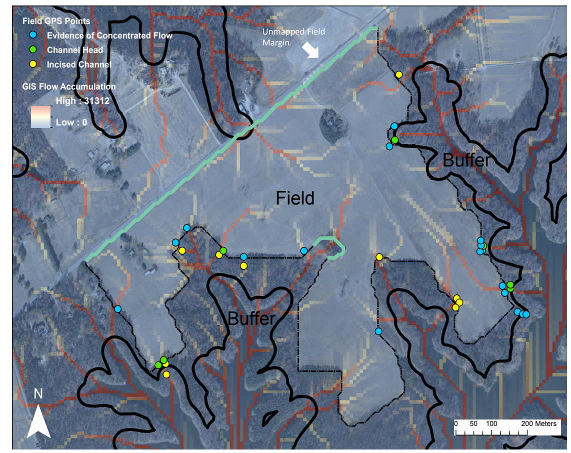


Figure 9. A field in James City County depicting the spatial relationship between the GPS points taken in the field at channel locations and the predictions of locations with high flow accumulation given by GIS. The comparison shows that all sixteen locations observed in the field to have evidence for channelization and concentrated flow coincided with places of high flow accumulation in GIS.

Conclusions

- Flow accumulation is concentrated in a small number of discrete locations along the field margin
  - Margin points with greatest drainage area capture from ~10% to ~50% of the total field area and the top five points capture ~40% to ~90%
- All channels observed in the field are near points of high flow accumulation determined in GIS
  - Channelization in the adjacent riparian buffer may occur more readily in places with high flow accumulation
- High drainage area in topographic lows is likely inherent in the nature of topography
  - Flow is likely not widely disseminated across buffers
- Smart riparian buffer design may rely on topographic analysis (Dosskey, 2002; Tomer, 2009)

References

Boesch, D.F., Brinsfield, R.B., and Magnien, R.E., 2001, Chesapeake Bay eutrophication: scientific understanding, ecosystem restoration, and challenges for agriculture: Journal of Environmental Quality, v. 30, p. 303-320.

Dosskey, M.G., Helmers, M.J., Eisenhauer, D.E., Franti, T.G., and Hoagland, K.D., 2002, Assessment of concentrated flow through riparian buffers: Journal of Soil and Water Conservation, v. 57, p. 336-343.

Lowrance, R., Altier, L.S., Newbold, J.D., Schnabel, R.R., Groffman, P.M., Denver, J.M., Correll, D.L., Gilliam, J.W., Robinson, J.L., Brinsfield, R.B., Staver, K.W., Lucas, W., and Todd, A.H., 1997, Water quality functions of riparian forest buffers in Chesapeake Bay watersheds: Environmental Management, v. 21, p. 687-712.

Powell, J., and Kotula, A., 2012, Agricultural Best Management Practices: http://www.vcnva.org/anx/index.cfm/1,403,418,0,html/Agricultural-Best-Management-Practices (accessed February 2012).

Tomer, M.D., Dosskey, M.G., Burkart, M.R., James, D.E., Helmers, M.J., and Eisenhauer, D.E., 2009, Methods to prioritize placement of riparian buffers for improved water quality: Agroforest Systems, v. 75, p. 17-25.