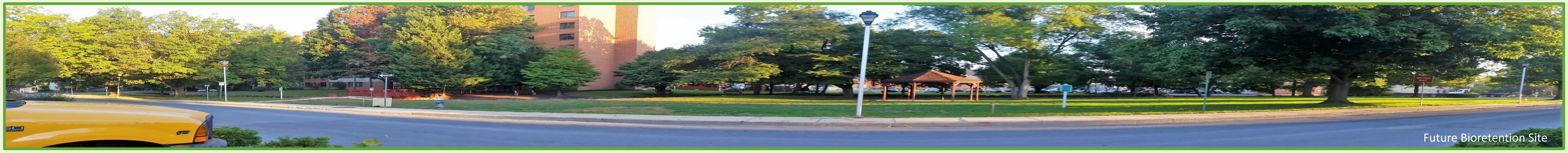
Analysis of Bioretention Basin Infiltration and Stormwater Runoff for Chambersburg Borough, Franklin County, Pennsylvania

Molly Eck (me5095@ship.edu) & Christopher Woltemade (cjwolt@ship.edu): Shippensburg University, Geography/Earth Sciences Department, Shippensburg, PA 17257



ABSTRACT

Bioretention is one of the most frequently used Best Management Practices (BMPs) to address stormwater runoff in urbanized watersheds. Rhodes Drive, in Chambersburg Borough, Franklin County, Pennsylvania is the proposed location of a bioretention facility, which will disconnect the direct delivery of stormwater from Rhodes Drive and the surrounding area to Falling Spring Creek, and provide stormwater management prior to being discharged. Data gathered from the Borough including a field report on soil properties, the project plan created by ARRO Consulting, Inc., contributing basin topography, as well as storm sewer maps were utilized using ArcMap and TR-55 software. The infiltration rate at three study sites within the future bioretention basin site was measured using a double-ring infiltrometer, and averaged to result in one average rate for the basin. TR-55 stormwater modeling software was applied to estimate runoff volume and peak rate of discharge. The efficiency of the basin in regards to the volume of runoff expected was analyzed based off of percent infiltration vs. overflow across a range of design storm events. Results of the study included 57 to 99 percent of runoff volume being infiltrated by the basin over a range of design 24-hour storm events, which would have otherwise been delivered directly to Falling Spring Creek. Such results indicate the successful effects the bioretention basin will have on the Falling Spring Creek sub-watershed.

Rhodes Drive Bioretention Site

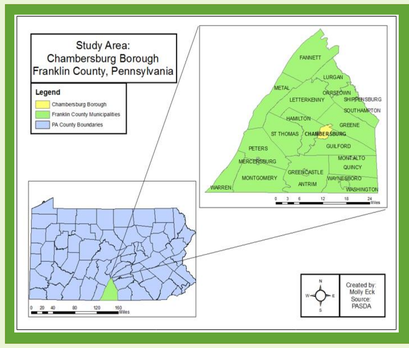
BIORETENTION AND INFILTRATION BACKGROUND

Urbanization leads to an increase in impervious land cover which typically slows rainfall infiltration, altering site hydrology, and degrades water quantity and quality (Endreny and Collins 2009). Bioretention is a BMP designed with the goal of minimizing surface water runoff volume (Morzaria-Luna et al. 2004).

- Basins maximize infiltration and vegetative growth (Roy-Poirier et al. 2010)
- Vegetation is selected for design and efficiency (Bohnert et al. 1995)
- Filtrate, absorb, and treat pollutants biologically (Davis et al. 2009)
- 50 percent reduction of total suspended solids (Birch et al. 2005)
- High ratio of inflow vs outflow (Hunt et al. 2006)
- Delay and reduce peak flows, and decrease runoff volume (Li et al. 2009)

RESEARCH QUESTIONS

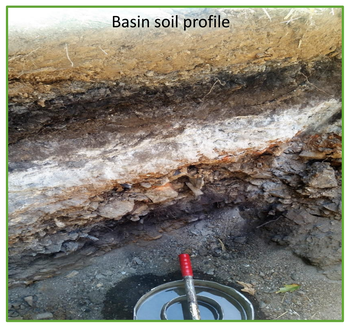
1. How much runoff does the study site currently produce under a range of storm magnitudes, and how will the implementation of the bioretention basin alter that?
2. What percentage of total runoff volume will be captured and infiltrated by the bioretention basin across a range of design storms?

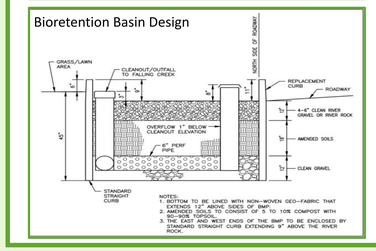


STUDY AREA

This study evaluates the Falling Spring Creek sub-watershed of the Potomac watershed, along Rhodes Drive in Chambersburg, Pennsylvania. The watershed drains an area of 2.10 acres. Chambersburg, Pennsylvania is characterized by:

- Limestone geology and Karst topography
- Highly urbanized land uses / high percentage of impervious surfaces
- Large variability in soil profile



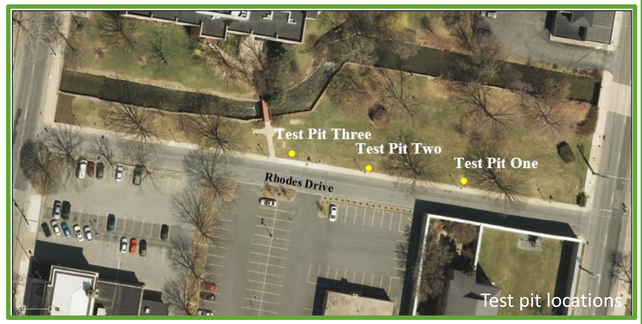


MODELING METHODS

- TR-55 stormwater modeling procedures were applied to estimate stormwater runoff volumes and analyzed with project design/dimensions to determine the volumetric function of the basin
- Rhodes Drive Field report was used to characterize soil properties at the study site
- Rhodes Drive Bioretention BMP Plan was used to interpret the design and dimensional details
- Contributing basin contour information was used to create a contributing watershed boundary map which was field checked to confirm accuracy
- Average curve number (CN) was calculated based on NRCS runoff CN values for urban land use
- Calculations were made using the TR-55 curve number method for 1-, 2-, 5-, 10-, 25-, 50-, and 100-year, 24-hour storm events
- Runoff volume, total infiltration, excess, storage volume, and overflow quantities were computed and input into an hourly water budget for each storm event to determine the functionality of the basin

FIELD METHODS

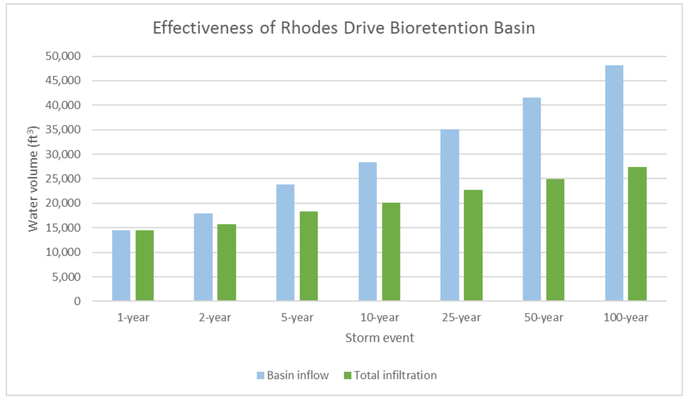
- Three 48 inch test pits were dug and equilibrium saturated infiltration rate was measured in each with a Turf-Tec double-ring infiltrometer at the base of each pit
- Final infiltration rate was calculated by determining the mean rate for the inner ring over the final 30 minutes of the test for each pit.
- Three rates were then averaged to get a mean infiltration rate for the entire bioretention basin



RESULTS

- Considerable variation of infiltration rates occurred between the three test pits:
  - Test Pit 1: 1.55 in/hr
  - Test Pit 2: 4.23 in/hr
  - Test Pit 3: 4.55 in/hr
  - Basin Average: 3.48 in/hr (1253 ft^3/hr)
- Total storage volume of 6,177 ft^3 was calculated using basin area and storage depth
- The average infiltration rate of the bioretention basin will result in the infiltration of 57 to 99 percent of the total runoff volume generated; depending on the storms' magnitude and frequency

Watershed Characteristics
Length: 233 ft
Slope: 0.03
Area: 2.10 acres
Average CN (D soils): 95
Manning's roughness coefficient (n): 0.011
Tc: 0.05 hr (used default of 0.10)



REFERENCES CITED

Alagna V, Bagarello V, Di Prima S, Giordano G, Iovino M. 2016. Testing infiltration run effects on the estimated water transmission properties of a sandy-loam soil. Geoderma 267:24–33.
ARRO Consulting, Inc. 2016. Rhodes Drive Bioretention BMP.
Biannaras W. 2016. Rhodes Drive Test Pits. ARRO Consulting, Inc. Job No. 10548.
Birch GF, Fazeli MS, Matthai C. 2005. Efficiency of an infiltration basin in removing contaminants from urban stormwater. Environ. Monit. Assess. 101:23–38.
Bohnert HJ, Nelson DE, Jensen RG. 1995. Adaptations to Environmental Stresses. Plant Cell 7:1099.
Borough of Chambersburg. 2016. Storm Sewer (MS4) Department [Internet]. Chambersburg(PA): [cited 2016 Sept 22]. Available from: http://www.borough.chambersburg.pa.us/government/stormsewer.html.
Borough of Chambersburg GIS Data. 2016. Chambersburg (PA): Christopher Bain - GIS Manager [cited 2016 Oct 28].
Climate Chambersburg-Pennsylvania. 2016. U.S. Climate Data; [cited 2016 Sept 12]. Available from: http://www.usclimatedata.com/climate/chambersburg/pennsylvania/united-states/uspa0258.
Davis, AP. 2008. Field performance of bioretention: Hydrology impacts. J. Hydrol. Eng.,13(2), 90–95.
Davis AP, Hunt WF, Traver RG, Clar M. 2009. Bioretention Technology: Overview of Current Practice and Future Needs. J. Environ. Eng. 135:109–117.
Dechesne M, Barraud S, Bardin J-P. 2004. Indicators for hydraulic and pollution retention assessment of stormwater infiltration basins. J. Environ. Manage. 71:371–380.
Endreny T, Collins V. 2009. Implications of bioretention basin spatial arrangements on stormwater recharge and groundwater mounding. Ecol. Eng. 35:670–677.
Franzluebbers A. 2002. Water infiltration and soil structure related to organic matter and its stratification with depth. Soil Tillage Res. 66:197–205.
Hsieh C, Davis AP. 2005 Nov 1. Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff. J. Environ. Eng. [accessed 2016 Sep 1]. http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9372(2005)131:11(1521).
Hunt WF, Jarrett AR, Smith JT, Sharkey LJ. 2006 Dec 1. Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina. J. Irrig. Drain. Eng. [accessed 2016 Sep 1]. http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9437(2006)132:6(600).
Johnson AI. 1963. A Field Method for Measurement of Infiltration. USGS general ground-water techniques Report No.: 1544–F. [accessed 2016 Sep 6]. http://pubs.usgs.gov/wsp/1544f/report.pdf.
Le Coustumer S, Fletcher T, Deletic A. 2007. Hydraulic performance of biofilters for stormwater management: first lessons from both laboratory and field studies. Water Science and Technology. [cited 2016 Sept 14] 56(10):93-100. Available from: http://wst.iwaponline.com/content/56/10/93.
Li H, Sharkey LJ, Hunt WF, Davis AP. 2009. Mitigation of Impervious Surface Hydrology Using Bioretention in North Carolina and Maryland. J. Hydrol. Eng. 14:407–415.
Morzaria-Luna HN, Schaepe K, Cutforth L, Veltman R. 2004. Implementation of bioretention systems: A Wisconsin case study - ProQuest. J. Am. Water Resour. Assoc. 40:1053–1061.
NRCS. 2004. Hydrologic Soil-Cover Complexes. National Engineering Handbook. [cited 2016 Nov 15] Available from: http://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/NEHhydrology/ch9.pdf.
PA Department of Conservation and Natural Resources. 2016. Great Valley Section Ridge and Valley Province [Internet]. [cited 2016 Sept 12]. Available from: http://www.dcnr.state.pa.us/topogeo/field/map13/13gvs/index.htm.
PA Department of Environmental Protection. 2004. Infiltration BMPs: Design Guidelines. Pennsylvania Department of Environmental Protection; [cited 2016 Sept 8]. Available from: http://www.dep.state.pa.us/dep/subject/advcoun/stormwater/2004/PADEP_OC_Mtg6.pdf
NOAA/NWS. 2014. NOAA Atlas 14 Point Precipitation Frequency Estimates: PA [Internet]. Silver Spring(MD): NOAA's National Weather Service; [cited 2016 Nov 14]. Available from: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=pa.
Quick Facts Chambersburg Borough, Pennsylvania [Internet]. 2015. United States Census Bureau; [cited 2016 Sept 12]. Available from: http://www.census.gov/quickfacts/table/PST045215/4212536.
Roy-Poirier A, Champagne P, Filion Y. 2010 Jan 28. Review of Bioretention System Research and Design: Past, Present, and Future. J. Environ. Eng. [accessed 2016 Sep 1]. http://ascelibrary.org/doi/abs/10.1061/(ASCE)EE.1943-7870.0000227.
Stormwater PA. 2012. Best Practices [Internet]. GreenTreks Network, Inc.; [cited 2016 Sept 15]. Available from: http://www.stormwaterpa.org/pennsylvania.html.
Stottlemyer A. 2016. Rhodes Drive Infiltration Test Pit Sites.
United States Department of Agriculture (USDA). 1986. Urban Hydrology for Small Watersheds - TR 55. [cited 2016 Sept 16] Available from: http://www.nrcs.usda.gov/Internet/FSE_Documents/stelprdb1044171.pdf.
United States Department of Agriculture (USDA). 2013. Web Soil Survey. Natural Resources Conservation Service; [cited 2016 Sept 15]. Available from: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.
United States Environmental Protection Agency (US-EPA). 2016. Stormwater Discharges from Municipal Sources. [cited 2016 Oct 25]. Available from: https://www.epa.gov/npdes/stormwater-planning.
USDA Natural Resources Conservation Service. 2008. Soil Quality Indicators. [cited 2016 Oct 28]. Available from: http://www.nrcs.usda.gov/Internet/FSE_Documents/nrcs142p2_053289.pdf.