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Final Report

Effective Strategies for Reducing Nutrient Loads from the Opequon Creek Watershed of Virginia and West Virginia

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Summary of Accomplishments

The goal of the project was to take a broad view of the urbanizing Opequon Creek watershed regarding issues and practices to reduce nutrient loads from the watershed. We enhanced our understanding of the watershed condition and dynamics through monitoring and modeling, identified barriers to adoption of improved practices, used educational programs and demonstration projects to work at overcoming barriers, implemented and evaluated innovative BMPs as new and remedial stormwater management practices that are adoptable (acceptable to stakeholders) and that benefit sediment and nutrient trapping and improved hydrology of urbanized streams. Evaluation of nutrient offset opportunities for the Frederick-Winchester Service Authority found nonpoint source options to be financially and administratively unattractive. We implemented several high-profile BMPs that will have a benefit to water quality, but more importantly serve as demonstrations of partnerships, procedures, and practices to the community, developers and governments. We used public education and workshops to promote practices, and worked to implement the Great Valley Stormwater Alliance and other efforts that will help ensure continuity and sustainability.

Project Activities

The project was a collaboration of faculty from Virginia Tech and West Virginia University, working in the Opequon Creek watershed which incorporates area in two states and across multiple jurisdictions. This Opequon Targeted Watershed Project (OTWP) involved a large number of partners and collaborators including state and federal government agencies, local governments, developers, and local stakeholders who were instrumental in almost every aspect of the project implementation. A key element of our project was employing a "watershed coordinator" (Jim Lawrence) who was a local presence and "activist" that could keep in close touch with issues, activities, and persons in the watershed. As proposed, the primary focus of the project was on understanding the sources and factors involved with nutrients coming from a watershed under very active development and land use change. The broad scope of activities including monitoring and modeling to characterize and understand the watershed system, implementation and evaluation of best management practices (BMPs), and evaluation of opportunities for nutrient offsets for the Frederick-Winchester Service Authority (FWSA). The basic goals of the project were addressed through the following tasks.

- Monitor Opequon Creek and tributaries to quantify nutrient contributions of different tributaries in the watershed, with the goal of identifying 'hot spots' and landuse impacts on nutrient export.
    - Bi-weekly sampling of up to 50 stream locations in the watershed for nutrients and bacteria from 2006-2009. A two-time snap-shot sampling of over 150 sites in the watershed. The sampling and analysis was a partnership with the Frederick-Winchester Service Authority and Friends of the Shenandoah River (FOSR).
    - Monthly and selected storm event sampling of Opequon Creek at the three USGS flow gauging stations. Contracted with the USGS and Virginia State Laboratory to conduct sampling and analysis.
- Implement and encourage adoption of management practices for stormwater management (quantity and quality) for developments and urbanized areas and for agriculture
- Implement and monitor innovative BMPs to determine the effectiveness for nutrient reduction
- Identify barriers to adoption for implementation of best management practices, and work at ways to overcome those barriers
    - Conduct stakeholder and landowner surveys to identify watershed problems, cleanup strategies, and obstacles to implementation of stormwater BMPs within the watershed.
    - Conduct educational programs and workshops to support and encourage the adoption of BMPs
- Define the opportunities for using nutrient offsets to meet nutrient reduction goals for the Frederick Winchester Service Authority (FWSA). Develop a screening model to assist in evaluating the economics of candidate offsets.
- Evaluate nutrient management alternatives for the Opequon Creek watershed through modeling studies:
    - Develop modeling tools to facilitate analysis in karstic, mixed land use watersheds
    - Determine placement of agricultural best management practices (BMPs) in the Opequon watershed in order to meet nutrient reduction goals using a combined watershed and economic analysis model.

There were a number of challenges and factors beyond our control that impacted the project (such as economic downturn and drought), yet we adapted to these major challenges and had significant results. Further, very dry periods following the initiation of the field studies resulted in little runoff thus limited data collected regarding BMP impacts. On the one site (Hedgebrook pocket wetland BMP) we were able to collect data and complete a study by pumping water from the stream to create artificial runoff events.

A number of the specific goals and activities of the project turned out to not be feasible or possible for a variety of reasons. Regarding BMP implementation, we learned firsthand the 'barriers' to adoption (described in more detail below) that made it impossible to implement the BMP monitoring plan as initially envisioned and proposed. As a further complication, once we were able to identify cooperators and establish a limited number of monitoring stations, then we had very dry rainfall periods and no stream flow. The ultimate result was very limited data from BMP studies that were insufficient to quantify efficiencies of nutrient removal. While some of the specifics of the project changed, the overall focus on improving water quality from the Opequon Creek was maintained and opportunities for impacting that larger goal were pursued. The stream water quality data collected show that nutrients in the Opequon Creek are distributed between all subwatersheds with little distinction between predominantly agricultural versus development. Stormwater management in developing areas became the primary focus of the project as this landuse represents the greatest impact on the hydrology and water quality of the Opequon.

Project Results

Barriers to the Implementation of Best Management Practices

Identifying barriers

Project implementation (putting BMPs on the ground) faced many of the same barriers that the development community and environmental advocates have faced. We identified barriers to adoption of BMPs, not as an academic exercise, but through the practical experience of working to implement BMPs ourselves as part of the project activities. These barriers, we discovered, are significant. In spite of many contacts and many partially developed plans, getting commitments from landowners, developers, and other responsible parties proved to be time-consuming, challenging, and more often than not, impossible. In addition to our direct experience, the input from questionnaires, interviews, and conversations at a number of workshops also provided broader background from others involved in stormwater management. We summarize some of the broader, key factors in the following points.

Economic downturn

Since 2006 development has slowed substantially which has all but eliminated opportunities to collaborate with developers and engineers. Massive staff reductions in both the public and private sectors and strains to local government budgets have made in-kind and pro bono assistance almost non-existent. It was difficult to persuade developers to implement BMPs during an economic downturn when profit margins are decreased and the public is not as fervent about the adverse impacts from growth. Historically advocates in the watershed had considerable success in obtaining concessions from developers during periods of expansion when there was a strong no-growth sentiment in the community.

Regulatory uncertainty

Regulatory uncertainty regarding certain issues (offset alternatives, nutrient allocations, stormwater regulations in Virginia, and wetland mitigation protocols) represent moving targets that have prevented partners from committing to projects. Also, in a multi-jurisdictional watershed there is a lack of uniformity in terms of approach to stormwater management. Frederick County, Virginia, has been most resistant to any change in regulations or in accepting local responsibility for stormwater. Other localities in the watershed are permitted MS4s and their programs vary. Berkeley County (WV) has progressive regulations but limited technical staff and no capacity for outreach and education, while the City of Winchester has minimum regulations and adequate technical staff but education and outreach are targeted towards homeowners. None of the localities initiate any professional educational opportunities for the development community. However some localities avail themselves to workshops organized by others -- an example being the Great Valley Stormwater Alliance workshops.

Fragmented & disparate knowledge base

There is a general lack of technical expertise and experience across all sectors. This is not new issue, but it continues to be a concern. Without collaborative multi-sector educational initiatives the knowledge base becomes decentralized and lacks generally accepted principles among the various practitioners. Local governments are driven primarily by MS4 permits, while advocates and non-regulatory agencies focus on TMDL plans and other voluntary measures, and designers must focus on the bottom line for the client. Many factors come into play, but without common ground it is a challenge to promote BMPs where the knowledge base is fragmented and disparate.

Project specific barriers

Technical assistance was a major obstacle to moving the BMP projects forward. Many opportunities were presented as potential projects. Some received initial approval and support from landowners and localities through the development and presentation of renderings and conceptual plans. However the majority required detailed engineering and design to be considered and approved. This technical assistance was difficult to solicit from the private and public sector for a variety of reasons and in-house capacity was minimal. As with the development community the availability of experienced technical resources is critical to promoting and implementing BMPs.

Many potential projects outlined in the original proposal did not materialize for a variety of reasons, some due to the economy as mentioned above. Others would have benefited from additional investigation or firm upfront commitment from the landowner and partners. This problem is not unique to this project alone. There was a relatively short time frame between the pre-proposal and full proposal which included the holidays. It was difficult to keep the project partners engaged during this time period when more work should have been done to vet the proposed projects and firm up partner commitments. In the next seven months before the official project start date local construction activity began to seriously decline. Some of these factors could not have be predicted but one lesson learned would be to invest/allow more time for investigation and partner commitment prior to submission of a full proposal.

Overcoming Barriers to BMP Implementation

Due primarily to the economic downturn, collaborative partnerships with localities and the development community did not materialize. However an exciting partnership with the Fort Collier Industrial Park has allowed us to leverage resources by working with a variety of funders and local organizations including local vendors, landowners, and corporate tenants. We overcame the downturn barrier by raising awareness of a valuable local resource, the Redbud Run Greenway and trout fishery, which enabled us to solicit support for BMP implementation directly upstream. Work will continue beyond the current grant and there is interest in utilizing the Stormwater Benchmarking Tool developed by the Chesapeake Stormwater Network to identify additional retrofit opportunities.

Another strong local partnership was developed with Shenandoah University. Working together with ATR Associates, two innovative BMPs were proposed and eventually integrated into a major "greening" project which included the removal of 10,800 sq.ft. of impervious surface adjacent to Abrams Creek.

Both the Industrial Park and Shenandoah University are high visibility sites and these retrofit projects will include interpretive signage explaining the environmental benefits. Workshops will be conducted at both sites by local project partners and outreach will continue beyond the current grant.

It is unclear at this point when the new Virginia stormwater rules and regulations will take effect. One of the requirements is the establishment of local stormwater programs for all jurisdictions. This action may help to level the playing field within the watershed and will remove to some degree the regulatory uncertainty. The Chesapeake Bay TMDL may do even more to address the lack of uniformity between state stormwater requirements.

The workshops conducted by the Great Valley Stormwater Alliance will continue to bring stormwater practioners together to address technical and geographical issues associated with implementing Environmental Site Design and Runoff Reduction and Pollution Prevention Practices. Just as important, on a larger scale, the establishment of the Chesapeake Bay Stormwater Training Partnership will be a critical source of information to expand the stormwater knowledge base and strengthen the regional capacity to implement BMPs.

Implementation of BMPs

The following lists very briefly the major BMPs implemented through this project. These projects were prioritized because of the suitability for monitoring to study effectiveness, visibility, potential for longer-term partnership and educational impact, and of course, due to the willingness and interest of landowners to collaborate. While only a very brief listing is included here, a more detailed description of the implementation and impact of each BMP can be found in the attached Appendix A. In addition, more detailed 'photo journals' that shows before/after and implementation of the more innovative BMPs are attached.

Hedgebrook Farm Floodplain Wetland

- ¾ acre project located in a rural (agricultural) section of the upper watershed
- Designed to capture and treat storm flow runoff

Town Run Floodplain Wetland

- 2,000 sq.ft. urban demonstration project in the City of Winchester
- Inlet modified in November 2009 – now receiving high flows

Cedarmeade Pocket Wetland

- Practice installed by others to serve residential in-fill development
- Modified to increase practice performance and to support monitoring

Shenandoah University (SU) Retrofits (completed March 2010)

- Drop Inlet Bioretention – capturing "first flush" runoff to existing "traditional" structure increasing infiltration and pollutant removal
- Water Quality Swale (WQS) Retrofit – conversion of asphalt drainage ditch to a "hybrid" WQS which mimics the hydrology of a properly functioning stream channel. Vegetated conveyance system dissipates energy and improves water quality while meeting SWM requirements. Functioning natural system also serves as a landscape feature and an integral part of an extensive project to remove impervious surfaces adjacent to Abrams Creek

Fort Collier Industrial Park Projects

The 225-acre industrial park situated immediately upstream from two streams that provide the majority of the flow for the lower three miles of Redbud Run to its confluence with Opequon Creek. This section supports naturally reproducing rainbow trout and features a Greenway project, permanent land protection, and a developing environmental education program with Frederick County Schools. The development of the stormwater management projects, headed by the OTWP, represented a collaboration of diverse partnerships and funding sources. The industrial park owner and corporate tenants are committed to improve all environmental aspects – water quality, water consumption, energy use, ecological continuity, protection of downstream resources. The working relationship developed with the industrial park has a number of ongoing impacts:

- Identify and promote alternatives to turf cover and develop management guidelines
- High-visibility site to serve as demonstration for innovative practices and management – projects to continue beyond the OTW project
- Engaging employees and citizens in annual tree plantings

In addition to the partnership with the industrial park, funding for the immediate project was leveraged with contributions from: OTWP ($10,415), VA DEQ ($28,430), VA DOF ($22,330), and Greenway Engineering ($19,560 in-kind).

Major project components (completed May 2010) include:

- Sediment/Nutrient Treatment Train-2 sediment forebays & pocket wetland
- Grass Channel/Bioretention Retrofit (treating 1.78 acre parking lot)
- Floodplain wetland/restoration with micro pools
- Interpretive signage and workshops/tours planned (to continue beyond OTW project)
- Nutrient monitoring capability

Other related initiatives in the industrial park and Redbud Run watershed include:

- Dye-trace studies with USGS (Sunnyside Run is a "losing stream")
- Development of environmental education program
- Involvement of National Trout Unlimited--Shenandoah Headwaters Initiative
- Pilot project for TU's Conservation Success Index—GIS Watershed Analysis Tool.
- Storm water projects featured in winter 2010 issue of Trout Magazine

Friendship Park Drainage Area Retrofit

This project is serving as a pilot project in the City of Winchester to establish guidelines/policy for management of public lands (i.e., parks, schools, and drainage easements). Policy could lead to ordinance for private lands.

- Project developed in part by a student design team from the Biological Systems Engineering Department (May 2009) proposing naturalization of area to promote wetland functions to improve water quality
- Establishment of no-mow riparian zones (completed April 2010)
- Community-based riparian tree planting projects (completed April 2010)
- Promote interpretation of environmental benefits (ongoing by others)

Hiatt-Lick Run watershed

McCann Farm – 200 acre Century Farm amidst a rapidly urbanizing area situated in the middle of the Hiatt-Lick Run watershed. A major spring on the property provides the only sustained flows for the lower section to the confluence with Opequon Creek. OTW has worked closely with all landowners in the lower section as well as upstream landowners and developers in the surrounding area. Major components and outcomes from the project include:

- Use of private funds to install some “flexible” (reduced setback) fencing
- Citizen Monitoring Training → McCann family interest, student project by Kathryn McCann monitored bacteria in stream associated with cattle access
- OTW – Installation of ISCO samplers and weather station
- OTW – Installation of level loggers on major tribs downstream
- OTW – Benthic Macro Invertebrate Study performed by Shenandoah University
- Extensive bi-weekly sampling in the watershed
- Baseline data collection to quantify effects from landuse change and BMP implementation – ability to become long term research watershed
- Interest from USGS in groundwater resources
- Comfort level with “flexible” fencing and good working relationship with owners are key factors in decision to exclude cattle using creative mix of state & federal cost/share programs
- Linear feet of fencing installed
    - Flexible fencing (private funds from Potomac Conservancy) 2,081 lf
    - State cost/share – 1,020 lf
    - CREP – 2,908 lf
    - CREP acres 10.5

The McCann Farm, along with other “flexible” fencing projects in Rockingham County, demonstrated to VaDCR the value of allowing reduced buffers in order to achieve full exclusion. A new state cost/share program for TMDL watersheds was created as a result: LE-2T Livestock Exclusion with Reduced Setback (10’ min.) at 50% cost share.

Evaluating the effectiveness of a floodplain wetland BMP

A 0.2-ha constructed floodplain wetland was implemented for attenuation of stormwater pollutants at Hedgebrook farm. The groundwater table and hydraulic gradients were monitored during the first two years of establishment in nested piezometers. The objectives were to 1) determine if jurisdictional wetland hydrologic criteria were met, 2) investigate the influence of groundwater in the annual hydrologic budget, and 3) identify spatial and temporal variability in groundwater hydraulic gradients. Wetland hydrology was determined to exist on the site during both years of study, as the water table was measured to be in the top of the soil profile during portions of the growing season. To determine the role of groundwater in the wetland water budget, a simplified water budget was evaluated and excluded groundwater exchange. The simplified budget did not reflect the observed hydroperiod, suggesting the groundwater component played a large role in the wetland water budget. Large spatial variability existed in hydraulic gradients, which were dominated by vertical conductivity. While not as great, hillslope effects on lateral hydraulic gradients also existed.

Controlled flooding experiments were performed to simulate overbank events at the constructed floodplain wetland in a consecutive fall and spring season. The objectives were to 1) characterize hydraulic parameters during overbank events, 2) evaluate the capacity of wetland macrotopographic features and vegetation to introduce flow complexity and mixing, and 3) quantify the role of macrotopography in the removal of suspended solids. A conservative tracer was injected at the wetland inlet and rapid sampling occurred during steady state conditions at three perpendicular transects as well as the inlet and outlet structure. Mean residence time was determined to be 100 min for flow rates of 4.3-5.1 m^3/min. Residence time distributions evaluated for the high and low marsh areas indicated significant mixing in both seasons. However, Manning's *n* was determined to be significantly higher in the spring event than in the fall, suggesting that the presence of rigid-stem vegetation in the spring season increased resistance to flow and potentially impacted the mean residence time of stormflow. Average wetland *n* was consistent with other published roughness values for emergent wetlands of similar depths at a value of 0.62. Total suspended solid concentrations decreased with increasing residence time during both experiments.

Stream water was amended with nitrogen and phosphorus and pumped through the wetland during the controlled pumping experiments. The objectives were to evaluate the event-scale nutrient attenuation capacity of the constructed floodplain wetland, 2) identify spatial variability in nutrient concentrations, and 3) identify temporal variability in nutrient removal between fall and spring seasons. Samples were collected at the inlet, outlet structure, and at three locations along three perpendicular transects along the wetland flowpath. Mass reduction of pollutants were 73% TSS, 54% NH_3, 16% NO_3, 16% TN, 23% PO_4, and 37% TP in the fall, and 69% TSS, 58% NH_3, 7% NO_3, 22% TN, 8% PO_4, and 25% TP in the spring. Linear regression of mass flux over the event hydrograph was used to determine pollutant removal rates between the wetland inlet and outlet. Removal rates of all constituents were higher in the spring event than in the fall. Dissolved nitrogen species were more rapidly removed than dissolved phosphorus; however, TP removal rate was significantly faster than TN removal rate, suggesting that the dominate removal mechanism of phosphorus was settling of solids. Spatial variability in nutrient concentrations throughout the wetland was large and did not correlate to macrotopographic feature location.

Evaluation of urban nonpoint source offset opportunities with FWSA

A general spreadsheet "screening model" was developed to estimate the cost of acquiring nonpoint source offset under local jurisdictional control in the Virginia Nutrient Trading program. The screening model produces cost per pound of nutrients removed and total pounds of offset generated for three classes of NPS offsets: 1) urban stormwater BMPs, 2) septic-to-central sewer offsets, and 3) land conversion (agricultural land-to-forest/openland). The model and results were published in Stephen Aultman, *Analyzing Cost Implications of Water Quality Trading Provisions: Lessons from the Virginia Nutrient Credit Exchange Act*. (M.S. Thesis. Department of Agricultural and Applied Economics, Virginia Tech, Blacksburg, Sept 2007).

The results were shared and discussed in meetings and through internal discussion papers with the Frederick Winchester Service Authority (FWSA), a project partner and operator of two wastewater treatment plants in the watershed. The results indicated that most urban stormwater BMPs were infeasible on the basis of cost. Urban stormwater and septic-to-sewer offsets were unlikely to generate enough credits to be of practical use to a regulated point source. Land conversion, under some circumstances, might generate offsets at a reasonable cost, but were deemed unattractive as on offset option due to urbanization and a decline in the agricultural sector resulting in a lack of intensively cultivated cropland in the basin.

The limited appeal of the initial set of offset options required a redirection of efforts. The screening analysis shifted to exploration of more speculative (unapproved) regulatory offset options. Potential offset generating projects were refocused toward additional treatment of ambient water (managed wetland systems, reactive nutrient barriers), additional post treatment of wastewater flows, and gray water reuse options. All these offset options are site-specific, and in many cases, not yet approved by Virginia trading rules. All offset options explored allow the regulated point source (FWSA) to operate and control (rather than a third party offset provider). This was considered as a requirement for consideration.

Beginning in 2008, possible additional offset options were identified with FWSA. The screening analysis focused on regulatory and technical feasibility. Informal exploratory conversations with DEQ nutrient trading staff were conducted. In April 2009, representatives from DEQ, FWSA, Corps of Engineers, and selected project investigators participated in a field tour to explore options for generating offsets through wetland or natural area treatment of gray water or ambient water. Water withdrawal, wetland permitting, and offset regulatory feasibility were raised and discussed. Follow-up analysis and discussions concluded that managed wetland treatment was impractical because of the limited availability of suitable sites and the inability of existing sites to produce offsets on the scale needed.

Based on this evidence, an internal discussion paper (September 2009) summarizing offset option types was further refined and shared with FWSA and discussed with DEQ staff. These discussions revealed either numerous regulatory uncertainties involved in establishing offset options have yet to be resolved or more detailed technical analysis was needed (beyond the remaining resources of the project).

The project research and collaborative discussions with FWSA and regulatory agencies found that conventional nonpoint source offsets (urban or agricultural) are financially infeasible and/or administratively unattractive. The results of the screening analysis were summarized in a number of presentations, a MS thesis (Aultman 2007), and one peer-reviewed publication (Stephenson et al. 2010). These findings, along with the desire for the regulated sources to maintain operational control over offset activities, lead to focus attention on other offset options. Offset options that are based on enhancing the natural environment's potential to assimilate nutrients (wetlands, reactive barriers, etc) or a variety of grey water reuse options (in essence avoiding the discharge of waterwater flow altogether). Additional work is needed to clarify regulatory uncertainties and to provide a more detailed assessment of the technical, site specific feasibility of some of more promising offset options.

Watershed Assessment and Nutrient Status - Monitoring Results

The empirical assessment of watershed nutrient loading consisted of three main activities, a watershed-scale assessment, a temporal-spatial assessment, and a stormflow/baseflow assessment. Manuscripts with detailed descriptions are in preparation for publication, and only a brief synopsis of the overall work is included here.

Watershed-scale assessment

Land-use and associated practices are key factors in efforts to reduce nutrient loading. The objective of this activity was to examine from a spatial perspective the effect of land-use on nutrient loading, and to identify nutrient hotspots. We conducted three snapshot sampling campaigns covering the entire Opequon Creek watershed (in a snapshot approach, all sites are sampled in a short period of time). In each campaign we sampled 130-180 stream locations across a range of land-uses, from forested to developed and agricultural watersheds. The three campaigns covered a wide range of flow conditions and were conducted in June 2009 (medium flow), October 2009 (low flow) and March 2010 (high flow). All sampling was done during base flow conditions. The water samples were analyzed for dissolved inorganic nutrients and basic water quality measurements.

Phosphate concentrations were generally very low, except for portions of the main stem of the Opequon Creek associated with effluent discharges from waste water treatment plants (WWTPs). In these locations, concentrations were lower in March 2010 compared to June 2009, likely because of higher flows, hence a stronger dilution effect. Nitrate concentration on the other hand displayed large spatial variability, and there was a strong seasonal correlation, regardless of differences in flow. Points of higher nitrate concentration were typically associated with WWTPs, landfills, and intensive agriculture. Note however that these results correspond to baseflow sampling only, and do not address possible differences in nutrient loading between baseflow and storm flow; some of these aspects are addressed below.

The data reveals some association between land use (e.g. nutrient concentrations versus percent forested, urban, agricultural), but except for a few instances, there is not a clear relationship, likely due to the widely mixed land use, with forest, pasture, cropland, development,and rural residential (septic systems) widely distributed throughout the watershed. The lack of distinction between urbanizing and agricultural areas was somewhat surprising, and calls for a continued broad and unified approach to nutrient reduction that requires participation from all residents. The data reveal some association between land use (e.g. nutrient concentrations versus percent forested, urban, agricultural), but except for a few instances, there is not a clear relationship, likely due to the widely mixed land use, with forest, pasture, cropland, development,and rural residential (septic systems) widely distributed throughout the watershed. The lack of distinction between urbanizing and agricultural areas was somewhat surprising, and calls for a continued broad and unified approach to nutrient reduction that requires participation from all residents. There is some evidence for an association between lower nitrate concentrations and riparian forest corridors, and this could be due to basic landuse patterns and loading, reduced delivery, enhanced uptake and denitrification, or a combination of these factors. Such a relationship would also illustrate the limitation of watershed modeling approaches that are based on a lumped representation of the spatial landscape. Further, it illustrates that spatial location should be considered when estimating the effect of re-forestation on nutrient reduction.

Temporal-spatial assessment

Changes in nutrient loading over time can be indicative of changes in land-use and management, and can also reveal important processes with respect to nutrient inputs (e.g., point sources) and nutrient removal (e.g., forested buffers). The objective of this activity was to examine changes in nutrient loading over time for a range of watersheds with varying land-use. Also, for a selected study area (Hiatt Run and Lick Run) a related objective was to capture the effect of future residential development and cattle fencing practices. We conducted regular (2-4 week interval) synoptic samplings for 30-50 stations (mainly in Virginia) during the period May 2006 – Dec 2009. Except for a few storm events, the sampling was mostly done during inter-storm periods. The water samples were analyzed for dissolved inorganic nutrients and basic water quality measurements.

During the period 2006-2009, flow conditions were generally at or below average, including extreme low flows, as well as a few high flow events. This range in flow conditions proved to be useful for examining nutrient inputs as well as nutrient removal mechanisms. Typically, nutrient concentrations in stream water vary over the course of the year, which complicates identifying changes in nutrient loading (either from point or non-point sources). By examining changes in nutrient concentrations over a range of flow conditions (using discharge-concentration graphs), one can separate effects due to dilution of point sources, as well as concentration decreases due to natural removal mechanisms. Here we highlight the following three results:

Evidence of point sources:

Discharge-concentration graphs can provide clear evidence of point sources. Samples upstream and downstream of the Parkins Mills WWTP which is located along the main stem of the Opequon Creek in the upper watershed show an increase in nitrate and phosphate concentrations. This increase was most evident during medium to low flows, while at high flows the increases were less evident because of dilution effects; this observed indirect (negative) relationship between discharge and concentration is indicative of point sources. These samplings were conducted for a known point source. We used similar plots to identify possible unknown point sources (e.g., along Redbud Run, Mill Creek, Torytown Run, the landfill in Frederick County) and also the lack thereof (e.g., Town Run in Winchester).

Evidence of changes in nutrient management:
Recently, the Parkins Mills WWTP has been upgraded, and in 2009 the improved plant became (partially) operational. The resulting improvement in water quality is evident in the concentration-flow graphs. The subset of samples collected in 2009 illustrates that nitrate concentrations dropped considerably compared to previous periods, while phosphate concentrations remained unchanged. The latter is likely because the upgraded plant was not yet completely operational at the time of sampling (Jesse Moffett, FWSA, personal communication, March 26, 2010).

Evidence of natural nutrient removal processes:
While point sources produce an indirect (negative) relationship between discharge and concentration, natural removal mechanism can produce a direct (positive) relationship. For example, in the case of in-stream removal, nitrate concentrations can decrease at low flows, because of an increase in residence time (slower moving water) and an increase in contact between stream water and stream sediment. This is illustrated for sampling stations along Hiatt Run, where in the lower portion of the watershed the stream is bordered by a riparian forest, along which nitrate concentrations drop considerably during periods of low flow. This emphasizes the important role of riparian forests and the associated carbon-nitrogen linkages which are important for in-stream nitrogen removal.

Stormflow/baseflow assessment

Depending on watershed characteristics, nutrient loading could vary substantially over time as a function of flow, particularly over the course of a storm hydrograph. Examining these differences is critical to assess the importance of targeted nutrient reduction strategies (e.g., how important are stormwater management practices in terms of their overall ability to reduce watershed nutrient export?). The objective of this activity was to examine differences in nutrient loading between stormflow and baseflow. Data collection for this activity was subcontracted to the USGS. Regular (monthly) water samples were collected at three USGS gauging locations on the main stem of the Opequon Creek during the period Dec 2006 – May 2009. The sampling included both baseflow and stormflow events.

Water samples were analyzed for dissolved and particulate nutrients, including the inorganic and organic fractions, and basic water quality measurements. The sampling produced a valuable data set with information on most nutrient species, including particulate and organic nutrients, whereas most of our other samples were analyzed only for dissolved inorganic nutrients. Overall, the results showed that on average, nitrate is the main nitrogen species (82% of total nitrogen), but that for high flows organic nitrogen increases in relative importance (up to 30-40% of total nitrogen). The pattern for phosphorus is less clearly defined, because of the dominant contributions by WWTPs. For the Berryville gauge, on average phosphate is the main phosphorus species (85% of total phosphorus), and similarly as for nitrogen, the relative proportion of combined organic and particulate phosphorus increases with high flows (~60% of total phosphorus).

Hiatt-Lick Run baseline benthic macro invertebrate assessment

Shenandoah University student researchers sampled benthic macro invertebrates (BMIs) at six locations in the Hiatt-Lick Run subwatershed in May and October 2008. Methods and analysis conformed to the EPA's Rapid Bioassessment Protocols (RBPs) and the Virginia Stream Condition Index (VSCI) manuals, respectively. The VSCI is an eight-metric index based on the biodiversity, pollution tolerance and ecological niches of the BMIs collected in each sample. The mean VSCI score for the 11 samples was 43.5 on a 100-point scale, an overall water quality rating of "moderately stressed". VSCI scores for 8 samples fell into the severely or moderately stressed category, 2 were rated fair, while only 1 was rated good. The study provides baseline data and a sampling framework to evaluate land-use change in the lower reaches and livestock exclusion on the McCann Farm.

Watershed Management Planning – Modeling Analysis

Watershed planning using the WCMS model

The main aim of the modeling effort was to develop a methodology that can be used to reduce nutrient loadings entering the bay area and improve water quality in Opequon watershed by implementing four agricultural BMPs (nutrient management, cover crops, conservation tillage and grazing land management). An integrated approach to nutrient reduction was utilized by estimating three models: a water quality model, a nutrient fate and transportation model, and an optimization model to identify a least cost strategy for nutrient reduction.

Land cover and use for the Opequon River Watershed was created by digitizing features from the most current aerial photography. Digital orthophotos at a scale of 1:4,800 were used as the background spatial resolution. This imagery had a nominal pixel resolution of 1 meter. A combination of temporal dates were used to categorize the area. These included both true color and infrared imagery from 2009 and 2007. Using a minimal mapping unit of .5 acre, we first extracted all natural land cover types and then developed classes. Natural land cover was separated into forest, woodland, grassland, and water. Developed classes focused on agriculture uses such as row crops, pasture, and feedlots. Urban classes included residential, high intensity urban (impervious) and transportation. The classes were selected based on available loading rates using expected or event mean concentrations.

WCMS (Strager, et al. 2010) was used to derive both concentration and loading values for total nitrogen, phosphorous, and suspended solids. WCMS was developed to support decision-making and the management of water resources at a state-wide level in West Virginia and was adapted for this study to include drainage from the Virginia (southern) part of the Opequon Watershed. Specific hydrological analysis functions were combined within a customized GIS interface to provide decision support capabilities to both technical and non-technical users. Components of the system developed for the Opequon included: an overland flow path model that indicates optimum water quality sampling locations, flow estimation for all streams in an identified area, an in-stream water quality and loading model for pollutant levels, and a ranking model to prioritize treatment alternatives based on user defined criteria and preferences. The primary goals of this system were to provide consistent technical information related to natural watershed processes and to predict the impacts of alternative management scenarios for decision makers which were our analysis team for this project. WCMS is also currently being used by the West Virginia Department of Environmental Protection (WVDEP) to guide policy development and management decisions that address watershed and water quality issues throughout the state.

Literature-based loading ranges were assigned to different land cover types and used to estimate loadings within WCMS for the major tributary watersheds in the Opequon. For example, a barren land cover class can contribute 2,200 mg/L hectare on an annual basis. This is the average concentration for barren land during the course of a rainfall event. The loading values assigned to each land use and cover type are then multiplied by the runoff grid. This creates a cell-based annual loading grid. The cell based-loading grids were then tracked cumulatively across the landscape to calculate annual stream loadings for the streams in the watershed. Concentrations for each cell location were subsequently calculated by dividing the annual loadings by annual average stream flow.

Within the WCMS application for the Opequon, the user is also given the opportunity to modify land cover loading coefficients from default literature based values. This allows users to select values that better reflect local conditions such as soil type or topography (if available). The concentrations modeled by WCMS can be thought of as the maximum potential concentrations based on the available data and specific assumptions, including homogeneous stream width, depth, slope and streambed roughness. It is also assumed that all streams have the same reareation, pollution decay, and sediment oxygen demand rates. The transport of pollutants was considered to be conservative (values get averaged over changing flow conditions only) and no loss or decay of pollutant mass was considered. The methodology does not consider infiltration, interflow, ground water flow additions, or any atmospheric conditions such as temperature or evapotranspiration.

Watershed physical characteristics were modeled in PRedICT© optimization software to determine the costs of implementing each BMP and the reduction efficiencies for both N and P. Sub-watershed nutrient contributions were modeled using WCMS, an ArcGIS extension created by the Natural Resource Analysis Center at West Virginia University (a brief description of WCMS is provided below). Constrained least cost optimization models were used to determine allocation strategies for BMPs by sub-watershed. Nutrient contributions were established for each sub-watershed and along the main stem. The reduction goals utilized in this analysis were: 47% and 35% for nitrogen (N) and phosphorus (P) respectively in VA; and 37% and 35% for N and P respectively in WV.

Four optimization scenarios were evaluated: uniform, holistic, prioritization, and targeted reduction approaches. A uniform reduction approach evaluated each of the 17 sub-watersheds in the Opequon to meet a reduction goal. Using specific land use contributions, an annual cost of $5.9 million would be required to meet N and P reduction goals on 14 of the 17 sub-watersheds. The holistic approach is a scenario whereby the entire watershed's nutrient reduction strategy is evaluated to meet the nutrient reduction goal at the Opequon watershed mouth. However, no optimal solution was found for this approach using only agricultural BMPs. When BMPs were implemented on all acres of crop and pasture land, a total cost of $19.3 million was computed with only 43% of the reduction goal achieved for P and 42% for N.

In the third scenario, a prioritization approach targeted high priority sub-watersheds, identified using the WCMS nutrient levels and using a public participation prioritization exercise (described in section (2) below) in watershed management. The same three sub-watersheds were identified as high priority by both methods: Mill, Tuscarora and Middle Creeks. Using P as the only constraint, the total cost of BMP implementation for these three sub-watersheds under the Chesapeake Bay values was approximately $1.1 million compared to $282,000 using specific land use specific values. This study showed that nutrient reduction costs are much lower under specific land use contributions compared to Chesapeake Bay wide averages. The final scenario involved a targeted approach where reduction goals are to be met for both the Virginia and West Virginia parts of the Opequon watershed. No optimal solution exists for these two points of evaluation. As with the second scenario, when BMPs were implemented on all agricultural land, Virginia had 69% and 63% of reduction goals achieved for N and P while WV had 36% and 49% of reduction goals achieved for N and P, respectively.

Considering all assumptions and limitations, this approach is best used as a screening model to determine areas that are worse than others in a general sense. This is the main purpose of the water quality modeling results used in the Opequon. The results can then be used to compare reasons why one watershed or region is better or worse and investigate the causes of the spatial variability. The goal of the WCMS water quality modeling effort was to provide a consistent and comparable modeling approach with limited data for this watershed.

Representing karst features in watershed models

In the United States, karst ecosystems cover approximately 20 percent of the country and karst aquifers provide 40 percent of the water used for drinking. In karst-influenced watersheds, such as the Opequon, karst features such as sinkholes and sinking streams act as rapid pathways for carrying water and pollutants into streams and groundwater. Human activities on karst landscapes can present some special problems such as alterations to hydrologic regime, contamination of groundwater, ground subsidence, and damage to cave ecosystems. Modeling the features and response of a karst-influenced watershed is important to provide a better understanding of the interactions between surface and ground water and how water quality is affected by human activities.

Several models were evaluated to determine their ability to model both discharge and nutrient transport in karst watersheds. The Soil Water Assessment Tool (SWAT) model was found to be appropriate due to its capability to represent almost all of the hydrological processes, its user-friendliness, and its ability to generate most of the parameters from available data. Moreover, SWAT can represent nitrogen transformations and transport processes and calculate nitrogen loadings, which is critical for karst watersheds. While it has been widely used and found to be an appropriate prediction tool, it does not explicitly include the capacity to represent specific features characteristic of karst-influenced basins. Modifications were made to the SWAT 2005 code to simulate faster aquifer recharge in karst environments, and this version was further modified in this project to represent karst environments at the HRU scale. A new parameter ‘sink’ allows simulating the hydrology and nitrate transport in a sinkhole representing its unique landuse and soil characteristics, and a new parameter ‘ss’ partitions nitrate transported with water that is lost from sinking streams.

The SWAT-karst model was used to simulate discharge and nitrogen loadings within the Opequon Creek karst-influenced watershed, located in the Potomac and Shenandoah River basin in Virginia and West Virginia. In the Opequon Creek watershed, SWAT-karst using the HRU to represent sinkholes had a greater impact on watershed hydrology than the earlier model version.

A statistical evaluation found that SWAT-karst performed better than SWAT in predicting streamflow in a karst-influenced watershed. The SWAT-karst model offers the flexibility to represent the unique relationship between surface and ground water in karst features in an HRU.

Using an HRU to represent sinkholes can depict the associated variability of a karst landscape. The new variables 'sink' and 'ss' provide a mechanism to represent the nutrient transport through sinkholes and sinking streams. Sensitivity analysis showed that SWAT-karst was sensitive to the new parameters sink which can be used for model calibration and to represent water recharge and nutrient transport to aquifers outside the watershed boundary.

Outreach and Public Education

Numerous presentations, community surveys, and meetings both formal and informal, were undertaken in the outreach effort. A number of specific events are noted in the following section on 'Dissemination', but many significant interactions are undocumented and took place in the watershed, one-on-one with developers, citizens, landowners, and public officials with the project watershed coordinator (Jim Lawrence). In addition to the individual presentations listed, the following efforts represent a more concerted and potentially longer-term impact.

Great Valley Stormwater Alliance (GVSA)

The GVSA is a regional, multi-jurisdictional education initiative operating in the Eastern Panhandle of West Virginia and the Northern Shenandoah Valley. The partners include the Opequon Targeted Watershed and Rocky Marsh Targeted Watershed Projects, the Chesapeake Stormwater Network, the West Virginia Department of Environmental Protection, and the Virginia Department of Conservation & Recreation. The Alliance has the following objectives: provide current information, receive feedback from the design community, develop and vet guidance to overcome barriers to implementation, and encourage localities to become early adopters of innovative stormwater BMPs.

Through a series of surveys, workshops, and charettes, specific regional issues were identified, including adapting infiltration practices in karst geology, the need for technical guidance, issues with costs and funding for maintenance, and ways to fund local stormwater programs.

Outcomes from the Great Valley Stormwater Alliance collaboration have included:

Regional Stormwater Workshop, June 5, 2008, Shepherdstown, WV
- 60 attendees -- "stormwater practioners" designers, plan reviewers, etc
- Presentations on Environmental Site Design & Runoff Reduction Methodology
- Karst Roundtable – *Implementing LID Practices in Karst*
- Group forms to develop stormwater design guidelines for karst

Shenandoah Science Symposium -- October 27-28, 2008
- Partnered with USGS & Northern Shenandoah Valley Regional Commission
- Assisted in the planning and coordination of the Water Quality sessions
- Presentation on Alliance formation and karst technical bulletin

Regional Stormwater Network Workshop, November 6, 2008, Ranson, WV

- 55 attendees -- "stormwater practioners" designers, plan reviewers, & local decision-makers. Workshops included: *"Emerging Trends in Stormwater Management"*, and "*A Collaborative Approach to Developing Stormwater Guidelines in Karst"*
- Karst Technical Bulletin -- Presentation and facilitated input session
- Karst Workgroup expanded to develop next version

Stormwater Management Site Plan Design Charette – February 5, 2009, Middletown, VA

- Partnered with DCR and the Center for Watershed Protection
- 53 attendees -- "stormwater practioners," designers, plan reviewers, etc.

Regional Water Resources Policy Committee – April 22, 2009

- Presentation to quarterly local government forum on Runoff Reduction Methodology and Virginia stormwater rules & regs timeline

Chesapeake Stormwater Network Technical Bulletin

"*Stormwater Design Guidelines for Karst Terrain in the Chesapeake Bay Watershed* (Ver 2)

- Identified as a major barrier in early surveys conducted by GVSA partners
- Karst guidance identified as a need at June 2008 workshop
- Work group assembled and peer review coordinated by GVSA
- Work group comprised of federal, state and local government staff and private sector engineers, developers and geologists
- Peer review ongoing
- Presented to numerous audiences in 2009-2010 including a Chesapeake Stormwater Training Partnership webinar on 5/22/10

Stormwater Management in Your Backyard

The Runoff Reduction Methodology places a major emphasis on promoting micro practices that treat very specific impervious areas (i.e. roofs, driveways, etc). Public education and technical assistance is a major barrier. OTW has partnered with Rutgers University on a very successful program being implemented in New York, New Jersey, and Frederick County, Va. Entitled ***Stormwater Management in Your Backyard,*** the program provides training on design, construction, and maintenance of small- to medium-scale rain gardens. To date, the local program has:

- Conducted "Stormwater. What's the problem?" outreach to over 130 citizens
- Conducted design-build-maintenance training for 45 master gardeners
- Installed 1 residential rain garden at a local "farm day" attended by over 1,000 local residents
- Installed a medium-scale rain garden at a community center in an underserved area of Winchester in conjunction with the Boys & Girls Club and other local stakeholders (the overall project includes a community vegetable garden and rain barrels).
- Installed a large-scale rain garden at the New Market Town Hall treating runoff from 16,000 sq.ft. of impervious surface

Stakeholder Surveys

Planner/Policy Maker Surveys:

Two surveys were conducted concerning implementation of stormwater BMPs. The first survey was conducted as part of a Regional Stormwater Workshop held at Shepherdstown, WV on June 5, 2008. A second, smaller survey of elected officials in West Virginia about BMPs for stormwater management was conducted in July of 2008. The results of both surveys were summarized in written reports and circulated to Opequon Targeted Watershed [http://www.opequoncreek.org/Virginia.html] Project team members.

For the Regional Stormwater Workshop survey, most attendees were engineers (42%) or planners (32%). The most common employment was a consultant (42%) with the remainder being either with government agencies (16%) or in other positions such as academic researcher and public service district (PSD) representatives (16%). The vast majority of attendees operate in West Virginia. Virginia (42%) and Maryland (26%) also were represented.

On the evaluation forms, stakeholders attending this workshop noted a number of issues that did not get addressed. These included funding for stormwater management (SWM) in West Virginia, the need for regional uniformity among states in regulations to prevent developers from avoiding regulations by moving projects to the area of least resistance, coordinating SWM with Wellhead Protection Programs, and the need for better communication between state and local officials on low impact development (LID). One consultant noted that local officials in Jefferson and Berkeley counties and in Charles Town were in the process of rewriting their ordinances but that their proposed ordinances contradicted the recommendations from the workshop.

For the second survey, three interviews of elected officials within the Opequon Watershed were conducted on July 18, 2008 by Alana Hartman from the West Virginia Department of Environmental Protection and Alan Collins from West Virginia University. Elected officials included: Greg Corliss, Current County Commissioner in Jefferson County, William L. Stubblefield, Current County Commissioner in Berkeley County, and Lance Dom, Former Mayor of Shepherdstown, WV.

These interviews were conducted in Commissioner Stubblefield's office in Berkeley County and at Town Hall in Shepherdstown, WV. Issues discussed included high priority issues of growth, water quality and quantity concerns, awareness of stormwater management, what department or agency is responsible for stormwater, whether local or state regulatory control is preferable, what is their perception about the level of public awareness on stormwater, and what type of stormwater workshop they thought would be useful.

Riparian Landowner Surveys:

Mail surveys were designed for riparian landowners along Mill and Tuscarora Creeks in Berkeley County, West Virginia. Both of these creeks have been identified as priority sub-watersheds within the Opequon Watershed by the local watershed volunteer group, the Opequon Creek Project Team (OCPT). Survey objectives were to: (1) elicit interests in potential stream improvement projects among riparian landowners; (2) determine landowner perceptions of problems in these creeks; and (3) raise awareness of OCPT efforts to improve water quality in Berkeley County. Two page surveys were developed at West Virginia University and pre-tested using OCPT members.

The Mill Creek survey was mailed in April 2007 and the Tuscarora Creek survey was mailed in June 2009. All riparian landowners within each sub-watershed were sent a survey (85 for Mill Creek and 55 for Tuscarora Creek). These surveys were mailed with a cover letter from the Opequon Creek Project Team and surveys were returned to West Virginia University for analysis. Mailing addresses were obtained from the Berkeley County Assessor's Office. Excluding returned surveys due to inaccurate mailing addresses, a total of 40 surveys were returned in Mill Creek for an effective response rate of 51% and 28 surveys were returned in Tuscarora Creek for a response rate of 52%.

Main results from these surveys were:

- The primary land uses for riparian land was home/residence and agriculture. Along Tuscarora Creek, over 1/3 of landowners indicated their land also was used for wildlife habitat enhancement.
- For both creeks, the top three concerns among riparian landowners were trash, stream pollution, and streambank erosion.
- Among stream improvements, riparian landowners were most interested in streambank restoration and tree planting. Consideration of these improvements increased with government cost share among Tuscarora Creek riparian owners, but not among Mill Creek owners.
- Conservation easements and allowing public access for fishing and recreation were the improvements of least interest to landowners.
- Few riparian landowners were aware of either the total maximum daily load (TMDL) plan being prepared in the Opequon Watershed or the OCPT prior to receiving the survey.
- The surveys were successful in expanding riparian landowner interest in the local watershed group. For both surveys, over 2/3 of respondents (a total of 44) provided contact information in order to be informed about future activities of the OCPT.

Lessons learned

- Barriers are real but can be overcome. Progress and demonstration practices can happen when there are individuals committed to inform, educate, build partnerships, and work for collaboration.
- Continued emphasis on informing the public is essential, and better methods of outreach are needed. Those of us in the water quality and watershed management community may assume that the visibility of the Chesapeake Bay cleanup effort and the local and Bay TMDL studies would be common household knowledge. Yet the survey of riparian landowners on two streams (Mill and Tuscarora Creeks) found that few were aware of the TMDL or current watershed activities. However, the majority (over 2/3) had concerns and interests in stream improvement and wanted to be kept informed. The implication is

that at the 'grassroots' level, many are interested and concerned about land use impacts on stream health that are not informed or involved.

- Local knowledge provided the same priority sub-watersheds as watershed modeling. Thus, both sources of information are appropriate to incorporate into watershed decision analysis.
- Nutrient loading data from this watershed suggests that neither agricultural nor urban areas can be singled out as predominant sources of nutrient loading. The broad contribution of nutrients from across the watershed places realistic bounds on the overall nutrient reduction capacity of BMPs. A broad range of approaches are needed, from reducing sources, to 'treating' collected runoff, and enhancing natural nitrogen removal.
- Conventional nonpoint source offsets (urban or agricultural) are financially infeasible and/or administratively unattractive as nutrient offsets for a regulated point source. For the FWSA, urban stormwater and septic-to-sewer offsets were unlikely to generate enough credits to be of practical use. Land conversion, under some circumstances, might generate offsets at a reasonable cost, but were deemed unattractive as on offset option due to urbanization and a decline in the agricultural sector resulting in a lack of intensively cultivated cropland in the basin.
- An analysis of scenarios using a watershed-scale model found that using sub-watershed specific values for loading computations rather than Chesapeake Bay wide values yields much lower optimal costs in meeting nutrient goals, and that compliance with WV and VA reduction goals is more feasible at a sub-watershed level rather than at a watershed scale.

Dissemination

Workshops, Tours and other presentations associated with OTW projects:

Jim Lawrence. Presentations and tours of Shenandoah University stormwater projects for students, faculty and administration

Jim Lawrence. Presentations and tours of Fort Collier stormwater projects for owners, corporate tenants and local government staff

Jim Lawrence. Numerous "Stormwater. What's the problem?" presentations to civic groups, environmental groups, parks & rec staff, and high school students

Collins, A. 2007. Survey results about Mill Creek. Opequon Creek Project Team meeting, James Rumsey Technical Institute, Martinsburg, WV, July 10, 2007.

Meeting Presentations

Claessens, L., C.D. Heatwole and K. Stephenson. 2010. A geographic-based assessment of practices to reduce watershed nitrogen export from anthropogenic activities. Association of American Geographers Annual Meeting, Washington D.C., Apr 2010.

Collins, A. and M. Mojica. 2009. "What Do Riparian Owners Really Want? Survey Results from Virginia and West Virginia." Presentation at the USDA-CSREES National Water Quality Conference, St. Louis, MO, February 10.

Ludwig, A., W. Hession. June 2010. Patterns in Groundwater Hydrology of a Small Constructed Floodplain Wetland. Annual AEES Meeting. Quebec City, Canada.

Ludwig, A., W. Hession. March 2010. Hydrology and Nutrient Attenuation in a Small Constructed Wetland in the Floodplain of Opequon Creek, a Tributary of the Chesapeake Bay. Research Symposium of the Graduate Student Assembly of Virginia Tech. Blacksburg, VA.

Ludwig A., W. Hession. June 2009. A Constructed Floodplain Wetland in the Chesapeake Bay Watershed for Nutrient Attenuation from Stormflows of Opequon Creek. Annual AEES Meeting, Corvallis, OR.

Ludwig A., W. Hession, J. Lawrence. June 2008. Evaluating a Constructed Floodplain Wetland for Nutrient Removal Efficiencies. American Ecological Engineering Society, June 2008, Blacksburg, VA.

Stephenson, K. "Alternative Point-Nonpoint Source Trading Partners" Nutrient Trading and Implications on Mid-Atlantic Waters Workshop, Frederick Maryland, March 22, 2007.

Stephenson, K. "Virginia Nutrient Credit Trading: Review and Update of Nonpoint Trading Options." Pure Water Forum Annual Meeting, Harrisonburg, Virginia, May 2007.

Stephenson, K. "Nutrient Offsets in Virginia: Update and Alternatives Analysis" Virginia Rural Water Association Conference, Williamsburg, VA March 18, 2008.

Stephenson, K., and L. Shabman. "Concept to Reality: Common Myths about Water Quality Trading" Selected Paper, Canadian Agricultural Economics Society/Northeast Agricultural and Resource Economics Joint Annual Meeting, Quebec City, Canada, June 29-July1, 2008.

Stephenson, K. "An Evaluation of Nutrient Trading Options in Virginia" Presentation to the Chesapeake Bay Program's Scientific and Technical Advisory Committee. Annapolis Maryland March 10th, 2009.

Publications and Papers

Heatwole, C.D., M.L. Wolfe, B. Benham, W.C. Hession, J. Lawrence, K. Stephenson. 2007. The Opequon Creek Project – Reducing nutrient loads to the Chesapeake Bay from a mixed land use watershed. Paper No. 072131, presented at the Annual International Meeting of the ASABE, Minneapolis.

Stephenson, K., Stephen Aultman, Todd Metcalfe, and Alex Miller. 2010. An Evaluation of Nutrient Nonpoint Offset Trading in Virginia: A Role for Agricultural Nonpoint Sources? *Water Resources Research*. doi:10.1029/2009WR008228

Strager, M. P., J. J. Fletcher, J. M. Strager, C. B. Yuill, R. N. Eli, J. T. Petty, S. J. Lamont. 2010. Watershed analysis with GIS: The watershed characterization and modeling system software application. *Computers and Geosciences* 36:970-976.

Collins, A. et al., (in prep.). "What do riparian landowners want? Survey results from the headwaters of the Potomac River". To be submitted to *Society and Natural Resources*.

Additional manuscripts from the project are in preparation including at least 4 from monitoring studies and 2 from modeling studies. Citations will be provided as available.

Theses / Dissertations

Aultman, S. 2007. Analyzing the Cost Implications of Water Quality Trading Provisions: Lessons from the Virginia Nutrient Credit Exchange Act. M.S. Thesis, Department of Agricultural and Applied Economics, Virginia Tech, Blacksburg, September 2007.

Karigomba, W. 2009. A Spatial Optimization Approach to Watershed Water Quality Management: A Case of the Opequon Watershed. PhD Dissertation, West Virginia University, Morgantown, WV.

Ludwig, Andrea. 2010. Constructed Floodplain Wetland Effectiveness for Stormwater Management. Ph.D. Dissertation, Department of Biological Systems Engineering, Virginia Tech, Blacksburg.

Yactayo, Guido. 2009. Modification of the SWAT Model to Simulate Hydrologic Processes in a Karst-influenced Watershed. M.S. thesis, Department of Biological Systems Engineering, Virginia Tech, Blacksburg.

Poster Presentations

Ludwig A., W. Hession. November 2009. Groundwater Hydrology of a Small Constructed Riparian Wetland in the Ridge and Valley of Virginia. Annual Meeting of the AWRA, Seattle, WA.

Ludwig A., W. Hession. March 2009. A Constructed Floodplain Wetland in the Chesapeake Bay Watershed for Nutrient Attenuation from Stormflows of Opequon Creek. Graduate Student Assembly Research Symposium, Virginia Tech, Blacksburg, VA.

Ludwig A., W. Hession, J. Lawrence. July 2008. Evaluating a Constructed Floodplain Wetland for Nutrient Removal Efficiencies. American Water Resources Association. July 2008, Virginia Beach, VA. (First Place Student Poster Presentation Award).

Reference:

Heatwole, C.D., J. Lawrence, L. Claessens, W.C. Hession, K. Stephenson, A. Ludwig, M.L Wolfe, B. Benham, A. Collins, M. Strager, G. DeSouza. 2010. Opequon targeted watershed project final report. Biological Systems Engineering, Virginia Tech, Blacksburg.

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Appendix A. Innovative Stormwater Management Practices

Hedgebrook Farm Floodplain Wetland

Project Description/Scope of Work:

Hedgebrook Farm is located on the upper Opequon in Frederick County. It has been in operation since 1907 and is designated as a Virginia Century Farm. The farm began as an apple orchard, with a dairy business later added in the 1940's. The milking parlor is the only remaining glass-tubed milking machine in Virginia. This working family dairy farm, with over 50 Jersey cows, also focuses on the fall farm market, educational tours, demonstration farming, Young Farmers Camps, and specialty events. The owner/operator, Kitty Hockman has served as the Chair of the Winchester-Frederick tourism board and is a strong proponent of agri-tourism and support for sustainable agriculture along with the development of niche markets, and most especially best management practices. Livestock have been excluded from the creek since the dairy business began, and no pesticides are used in operations.

The floodplain wetland project is designed to treat nutrients and other pollutants during storm flow conditions when most of these pollutants enter the stream. Its location is ideal due to the land use upstream, which includes a considerable amount of livestock with access to the creek along with increasing residential development. The project involved grading to create low areas in the floodplain with an inlet to draw water from Opequon Creek at high flows and an outlet to return treated flows to the main channel. Both inlet and outlet flows were monitored. Bi-weekly grab samples were also taken immediately downstream.

The constructed wetland design follows recommendations and guidelines set forth by the Commonwealth of Virginia in the Virginia Stormwater Handbook (DCR, 1999). Armored inlet and outlet features will guide overbank flow from the Opequon Creek through the constructed wetland (Figure A.1). The designated wetland area is comprised of three depth zones, deep water (2,023 sq ft, up to 4 ft), low marsh (8,090 sq ft, 0.5 to 1.5 ft), and high marsh (10,112 sq ft, 0 to 0.5 ft). The wetland is surrounded by a 2-foot berm. The total project area is 0.68 acres (29,646 sq ft), and the treatment area totals 0.46 acres (20,225 sq ft).

During the preliminary design phase, the project received a great amount of local support. Technical assistance was provided by Eco-Logic Design, Reading Landscapes, and The Opequon Watershed, Inc whose co-president Sally Anderson also serves as the President of the Virginia Native Plant Society. Greenway Engineering provided 1’ topo for the entire 10-acre floodplain, and John Magistro (Wetland Alternatives) obtained the Nationwide 27 permit from the Army Corps of Engineers. The Opequon Watershed, Inc. received a $10,000 reimbursement grant from the Regional Water Quality Improvement Fund administered by the Virginia Departments of Forestry and Conservation & Recreation. The owner of Hedgebrook Farm who also runs a Bed & Breakfast facility on site has plans to construct a solar cabin in close proximity to the project, and the project partners will pursue additional grants for interpretation of the site, including walking trails, signage and viewing platforms.

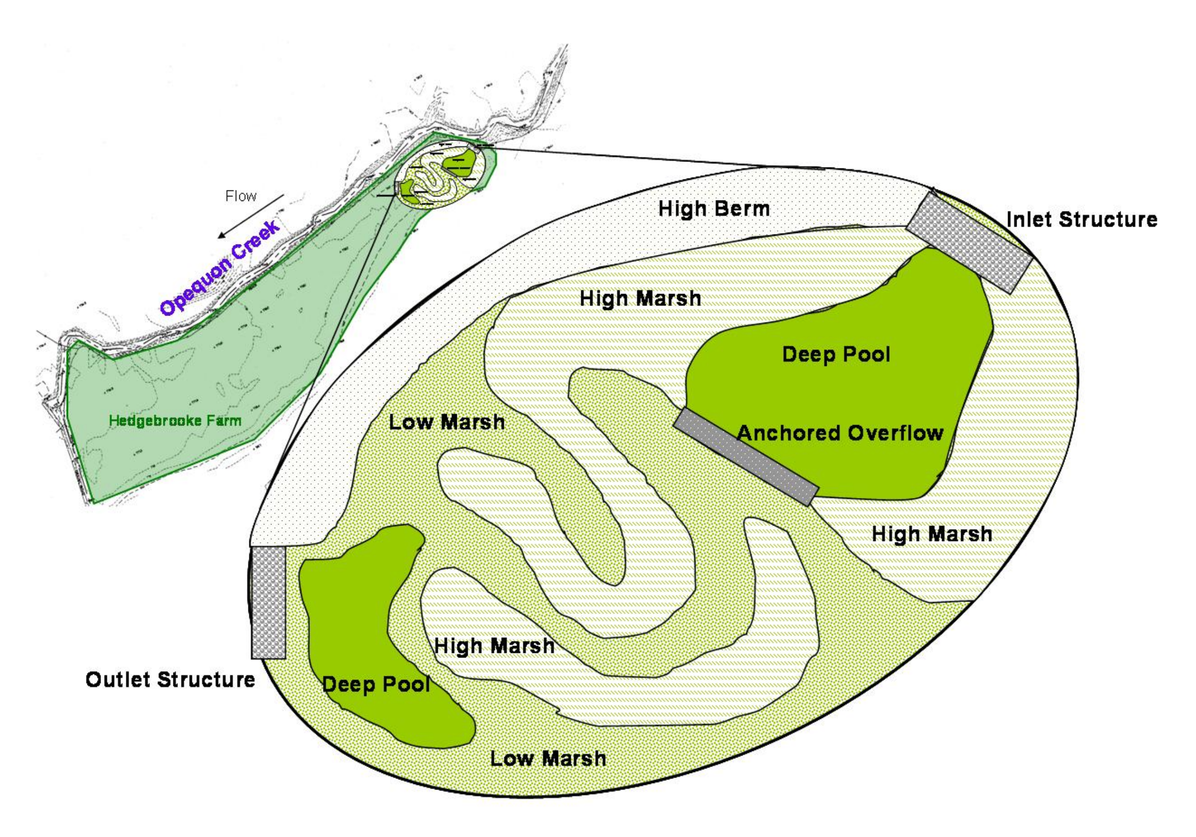

Figure A.1. Plan view of a constructed floodplain wetland along the Opequon Creek near Winchester.

Deliverables/Milestones

The project serves as a demonstration promoting innovative water quality improvement measures consistent with the Opequon TMDL Implementation Plan and the Chesapeake Bay Tributary Strategies. These innovative practices provide other benefits as well, including increased wildlife habitat along with the enhanced aesthetic and interpretive value of the project area. The floodplain wetland complements the existing educational opportunities at the farm and has become an important component of the Lord Fairfax Soil & Water Conservation District's K-12 environmental education program. Virginia Tech's Biological Systems Engineering Department and the Rutgers University Cooperative Extension Service conducted a rain garden training and installation at Hedgebrook Farm's Bed & Breakfast. Final planting for the pilot project, known as *Stormwater Management in Your Backyard*, coincided with Frederick County Farm Bureau's Family Farm Day in which over 1,000 people attended. The floodplain wetland was also part of the farm tour.

Two major components of the overall project are to quantify the nutrient removal capabilities of these "natural" practices and to develop strategies to overcome the barriers to implementation. These practices will be monitored with automated sampling devices programmed to work during storm events. One of the major barriers to implementing low impact development (LID) practices that utilize natural processes is long-term maintenance and management of the facilities. This will be a major focus of the project. Virginia Tech graduate students will maintain and manage the practices as a research project to establish long range management and maintenance guidelines.

Town Run Floodplain Wetland

Project Description/Scope of Work:

The Project is located along Town Run in the City of Winchester's Jim Barnett Park. Town Run is a spring fed stream with a drainage area less than five square miles. Town Run is also the major storm water collector for the city, and portions have been armored and channelized. The project is sited along one of the natural stretches and enhances the existing floodplain. The site is also adjacent to the Winchester Green Circle walking and biking trail that will eventually follow Town Run and Abrams Creek, encircling the city.

The project created a flow path and three micro pools covering approximately 750 sq ft in the floodplain adjacent to the channel. An inlet draws water at high flows, and an outlet returns treated flows to the main channel. Allowing high flows to access the floodplain improves water quality by dissipating energy, which helps decrease erosion and flooding downstream. A variety of wetland plants and shrubs provide nutrient uptake.

The project received a great amount of local support. Technical assistance was provided by Eco-Logic Design, Reading Landscapes, and The Opequon Watershed, Inc. The Winchester Joint Council of Garden Clubs donated $1,750 to support planting projects that improve water quality. The City of Winchester provided technical assistance and local forces for construction of the project. The Opequon Watershed, Inc. received a $7,150 reimbursement grant from the Regional Water Quality Improvement Fund administered by the Virginia Departments of Forestry and Conservation & Recreation.

Deliverables/Milestones

The project serves as a demonstration promoting innovative water quality improvement measures consistent with the Opequon TMDL Implementation Plan and the Chesapeake Bay Tributary Strategies. These innovative practices provide other benefits as well, including increased wildlife habitat along with the enhanced aesthetic and interpretive value of the project area. The floodplain wetland will complement the existing educational opportunities at the Shenandoah Valley Discovery Museum and Shenandoah University. The project has been part of the city's adult "green" education program and has been utilized for education & outreach associated with the city's MS-4 program. It has also provided field trip opportunities for Winchester area students.

Two major components of the overall project are to quantify the nutrient removal capabilities of these "natural" practices and to develop strategies to overcome the barriers to implementation. These practices will be monitored regularly and during storm events. One of the major barriers to implementing low impact development (LID) practices that utilize natural processes is long-term maintenance and management of the facilities. This will be a major focus of the project. VA Tech graduate students will maintain and manage the practices as a research project to establish long range management and maintenance guidelines, and the City of Winchester's new maintenance agreement for LID practices will be utilized.

The Town Run project is a small scale version of the Hedgebrook Farm project. It is ideal as a demonstration of an urban retrofit BMP.

Cedarmeade Pocket Wetland (modification & monitoring)

The primary goal at this site was to monitor the nutrient removal capabilities of this existing practice. An innovative approach to stormwater management to address upstream flooding concerns caused by in-fill residential development. It was a controversial development project which involved possible litigation between the developer and the City. A creative solution was put forth by the parties (city/developer/adjoining property owner). Three building lots were eliminated and dedicated as a pocket wetland to address the stormwater/flooding concerns. The project and decision making has been driven by political pressure rather than recommendations of the city engineer and others. This has been a major barrier to the effectiveness of the project and the ability to monitor performance. A last minute change to the original design added a "trickle trench" through the middle of the practice. In 2007 a grass swale which carried a majority of the flows to the practice was concreted.

Automated samplers were installed in late 2006 along with a level spreader to direct low flows laterally out of the trickle trench into the wetland. After the city installed the concrete swale upstream a compromise was reached to further mitigate the effects of the "trickle trench". Removal of the trench along with an additional structure to direct flows into the wetland was planned. The trench was left in place but a 48' long, 14" high level spreader was installed which has increased residency times within the practice. The drought and the numerous changes in the system, resulted in inadequate data to provide any meaningful evaluation.

Where do we go from here: Continued observation and modification to the practice to ensure that it is operating effectively is critical. This includes quantifying all inputs in order to accurately monitor the nutrient removal and retention capabilities of the practice. Barriers to effective implementation included a lack of understanding by local elected officials and stake-holders and insufficient technical guidance. Both these issues allow for political pressure to dominate the decision making process. There appears to be a tremendous potential to retrofit these types of practices in urban/suburban areas as they also satisfy local green space requirements. However as this projects demonstrated, they need to be carefully designed to be effective.

Shenandoah University – Stormwater Retrofit Projects

Background of Project Area/Description of Need:

Abrams Creek is on the state's impaired waters list for excessive bacteria and an inability to support aquatic life. A Total Maximum Daily Load (TMDL) was developed for Abrams and Opequon Creeks in 2003 with the primary stressor identified as sediment. A TMDL Implementation Plan for the entire Opequon watershed was completed in 2006.

Abrams Creek runs literally through the center of Shenandoah University (SU) which is located on the eastern (downstream) side of the City of Winchester. The University is taking steps to become more environmentally sustainable by decreasing impervious surfaces by outright removal and where practical installing pervious materials in new projects. The overall goal is to transform the campus from an urban automobile dependent/accommodating landscape to a more rural multi modal, natural setting as its name implies. The overall project included the removal of 10,800 square feet of asphalt roadway and parking immediately adjacent to Abrams Creek. The "upstream" stormwater retrofit projects along with additional green space will lessen the impact from campus runoff, some of which previously flowed directly to the creek.

Project Description/Scope of Work

The project has installed three interconnected stormwater management retrofit practices treating runoff from major buildings, parking areas and a central courtyard. Two bioretention practices have been incorporated into existing yard inlets located in the central court yard and an asphalt ditch has been converted to a water quality swale in the lower portion of the drainage area.

A) Asphalt ditch conversion to hybrid water quality swale/regenerative stormwater conveyance

Previously a majority of the runoff from the upper campus was conveyed directly through concrete pipes to an asphalt ditch and then to Racey Pond and Abrams Creek. This project involved the conversion of the asphalt ditch to a "hybrid" WQS which mimics the hydrology of a properly functioning stream channel by incorporating Regenerative Stormwater Conveyance design principles. This unique vegetated conveyance system dissipates energy and improves water quality while meeting stormwater management requirements for channel protection in respect to both erosion and flooding. The existing 100' straight line ditch with a 5 degree slope has been replaced by five curved sections that lengthen and widen the flow path. The sections are connected by plunge pools to decrease the slope of the individual sections and allow for sediment deposition.

Figure 1. Aerial view of existing swale area.

Figure 2. Existing swale looking north to pond.

Figure A.2. Water quality swale – Shenandoah University.

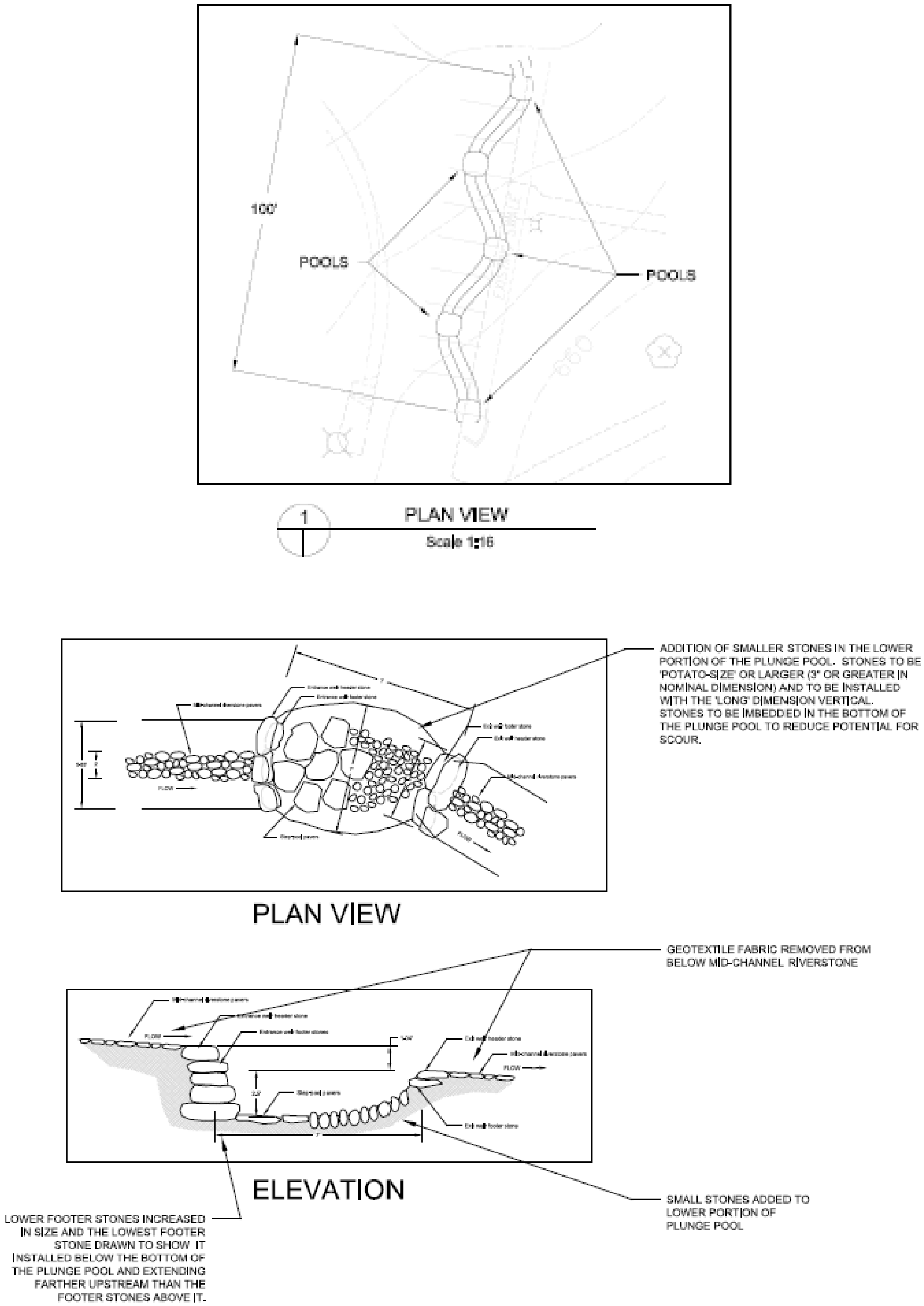

Figure A.3. Shenandoah University hybrid water quality swale plan details.

B) Drop inlet bioretention (DIB)

The 2.85 acre upper campus drainage area contains a central courtyard that is primarily turf cover where the two DIB units are located. This unique retrofit practice has broad applicability in many urban and *ultra* urban situations. The project involved excavating an area four feet deep surrounding the yard inlets to install a stone infiltration/storage base and an amended soil layer. A collar was added to raise the yard inlet and serve as an overflow standpipe. The upper unit receives runoff from the upper courtyard. The lower unit has a much smaller contributing area but will also receive flows from a partial roof disconnect at Howe Hall. As with the WQS these projects will be prominent features in the courtyard where graduation and other events take place throughout the year.

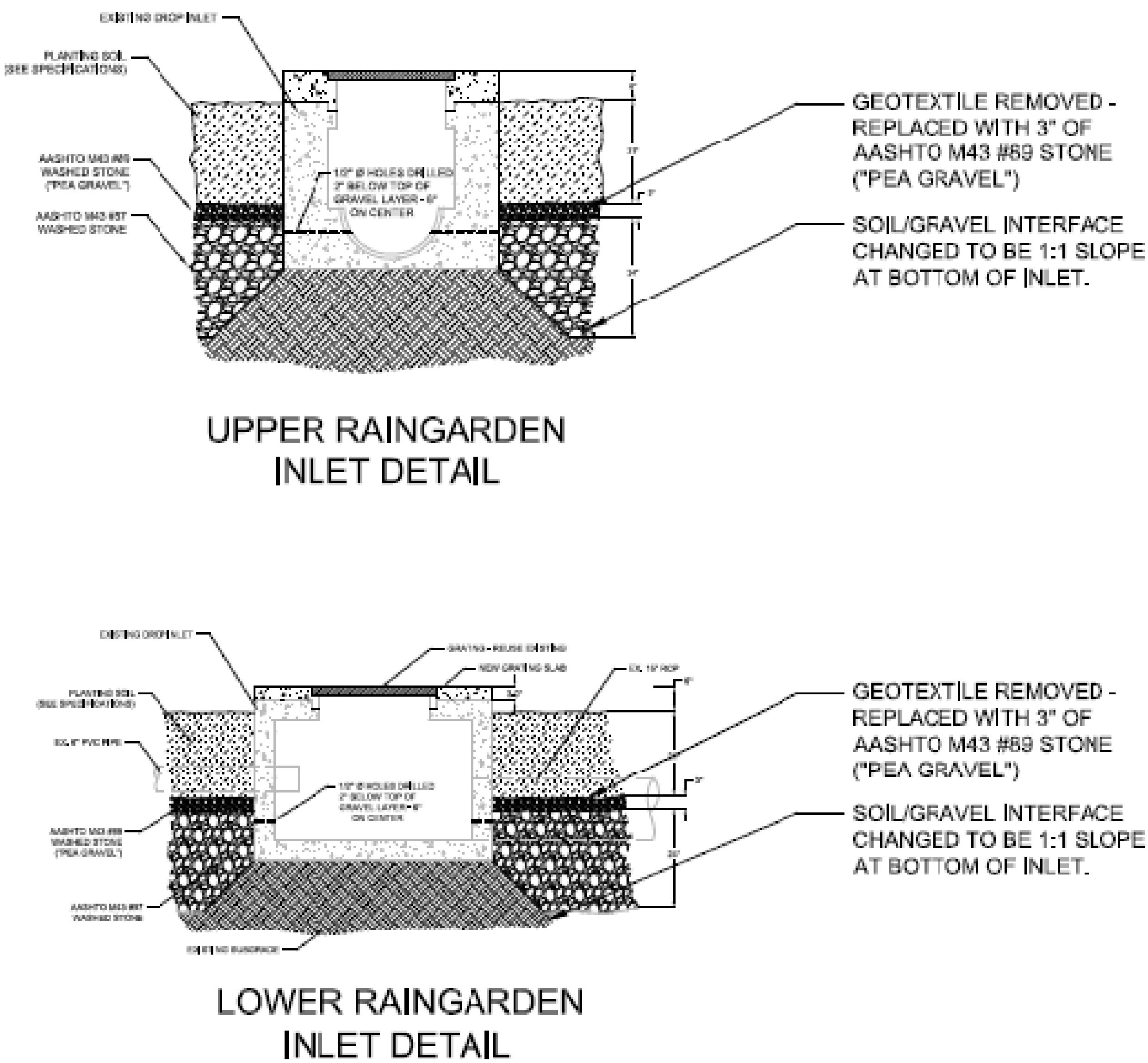

Figure A.4. Drop inlet bioretention details.

Implementation of these projects is the result of a unique collaboration between project partners. The President of Shenandoah University, the Physical Plant staff and the Environmental Studies Program faculty were all instrumental in supporting these innovative practices. All design work was performed by Richard Stanford of ATR Associates who generously donated the majority of his time and expertise. Coordination with the overall project was possible through the efforts of Patton Harris & Rust Associates and H&W Construction and The Opequon Watershed, Inc. received a $10,000 reimbursement grant from the Regional Water Quality Improvement Fund administered by the Virginia Departments of Forestry and Conservation & Recreation.

Deliverables/Milestones

The project demonstrates two unique retrofit practices in a high visibility setting that is accessible to the general public. Neither of these practices have previously been implemented in the Northern Shenandoah Valley.

The DIB retrofits are most unique. There are several manufactured units based on a similar concept but they are primarily focused on storage in *ultra* urban settings. This design is a low cost alternative that provides additional water quality benefits utilizing plant material and amended soils for nutrient uptake and pollutant removal. .Where prudent a berm can be added on the downstream side which will allow for a cost effective option to increase inlet extension and decrease excavation. The multiple benefits also include the aesthetic value these practices have as low maintenance landscape features. In some settings larger units could include elevated boardwalks, interpretive signs and larger trees to also increase urban tree canopy.

The WQS is equally innovative for the region. It has great potential as "last line of defense " retrofit in areas where storm flows are currently conveyed to streams in large pipes or open impervious swales. This "hybrid" practice could adapt well in riparian areas where mitigation is desired in conjunction with other practices such as floodplain wetlands, floodplain restoration and natural stream buffers. Dissipating energy from these types of sources is a major challenge when designing stream restoration projects; this practice is an alternative to the rip rapped swale and can be designed to meet MS-19 requirements while also improving water quality.

Outcomes

These projects will raise awareness throughout the region about innovative alternatives to traditional stormwater management practices. The demonstration opportunities have the ability to reach multiple sectors of the community.

The project will allow decision makers to become more familiar with the concept of small interconnected practices that can be retrofitted to provide a cumulative effect to improve water quality. The development community and especially the stormwater "practioners" (i.e. engineers, landscape architects and local plan review staff) will be able to see a "suite" of innovative practices in one location. A floodplain wetland along Town Run and the area's first rain garden, and largest with under drainage, are also located close by in Jim Barnett Park. These projects can also be part of the outreach effort associated with the new Virginia stormwater management regulations. The Great Valley Stormwater Alliance which works in the Northern Shenandoah Valley and Eastern Panhandle of West Virginia will plan a workshop in 2010 to highlight these projects

As part of an ongoing environmental education initiative these projects provided an opportunity for "hands on" learning by involving students and faculty in the construction and long term maintenance of the practices. The concept behind the DIB practices can be applied at a smaller scale on residential properties. Advancing the notion that rain barrels and roof disconnects have environmental benefits beyond water reuse and groundwater recharge; they can have a significant impact on runoff reduction and urban stormwater management.

Fort Collier Industrial Park - Stormwater Retrofit Projects

Background of Project Area/Description of Need:

Redbud Run and Opequon Creek are on the state's impaired waters list for excessive bacteria and an inability to support aquatic life. A Total Maximum Daily Load (TMDL) was developed for Opequon Creek in 2003 with the primary stressor identified as sediment. A TMDL Implementation Plan for the entire Opequon watershed was completed in 2006.

The project, located in the upper two-thirds of the Redbud Run watershed, will provide critical protection for the lower section where a greenway and trout fishery is being developed. This three mile lower section drains directly to Opequon Creek and receives a majority of its flow from two major springs. The upper section is within the Frederick County Urban Development Area (UDA) and a small part of the City of Winchester and it contributes primarily storm flows to the lower portion. Lower Redbud Run supports naturally reproducing Rainbow Trout and a project began in 2003 to reintroduce native Brook Trout. The owners of the Fort Collier Industrial Park are working collaboratively with the project partners to implement urban best management practices along Sunnyside Run and Redbud Run and through modifications to the existing storm water management systems. The Park will serve as a demonstration for a variety of structural and non structural practices that emphasize utilizing natural processes through restoration of floodplains and forested riparian buffers. The property encompasses over 220 acres and represents the last line of defense upstream of the major springs that provide the critical cold water flows for the lower Redbud Run Greenway

Project Description/Scope of Work

As described above the Fort Collier Industrial Park is located at a critical point within the Redbud Run watershed where Sunnyside Run and Redbud Run converge. The projects are focused on Sunnyside Run an intermittent stream with a 2.25 square mile contributing area comprised of primarily urban land-uses. The three distinct stormwater management projects described below will each address a specific impact to the stream.

A) Upper Sunnyside Run-Enhanced Sediment Forebay/Pocket Wetland

This project is located at the Southeastern Container facility, a Coca Cola subcontractor, and will treat flows from commercial/industrial properties adjacent to the Fort Collier Industrial Park. The total drainage area is 9.37 acres and is comprised of a concrete manufacturer and office headquarters (Shockey LLC) and a masonry products retail sales facility (Frederick Block, Inc.).

The area is 86% impervious surface. During most rain events dust from the masonry products produces a considerably amount of sediment. These loads were previously conveyed directly to the stream via a conventional grass channel, culvert pipes, a small tree-lined swale and finally sheet flow.

This project provides primary treatment for sediment deposition and secondary treatment for nutrient removal. An existing grass channel was modified to serve as a sediment forebay/pond and a second sediment forebay was constructed upstream of the pocket wetland. The forebays were designed as natural features utilizing native plants, and major consideration was given to ease of maintenance. Secondary treatment is provided by a pocket wetland that consists of a high and low marsh and a 20’ wide vegetated level spreader outlet to the stream. Native wetland plants, grasses and shrubs were planted to provide nutrient uptake.

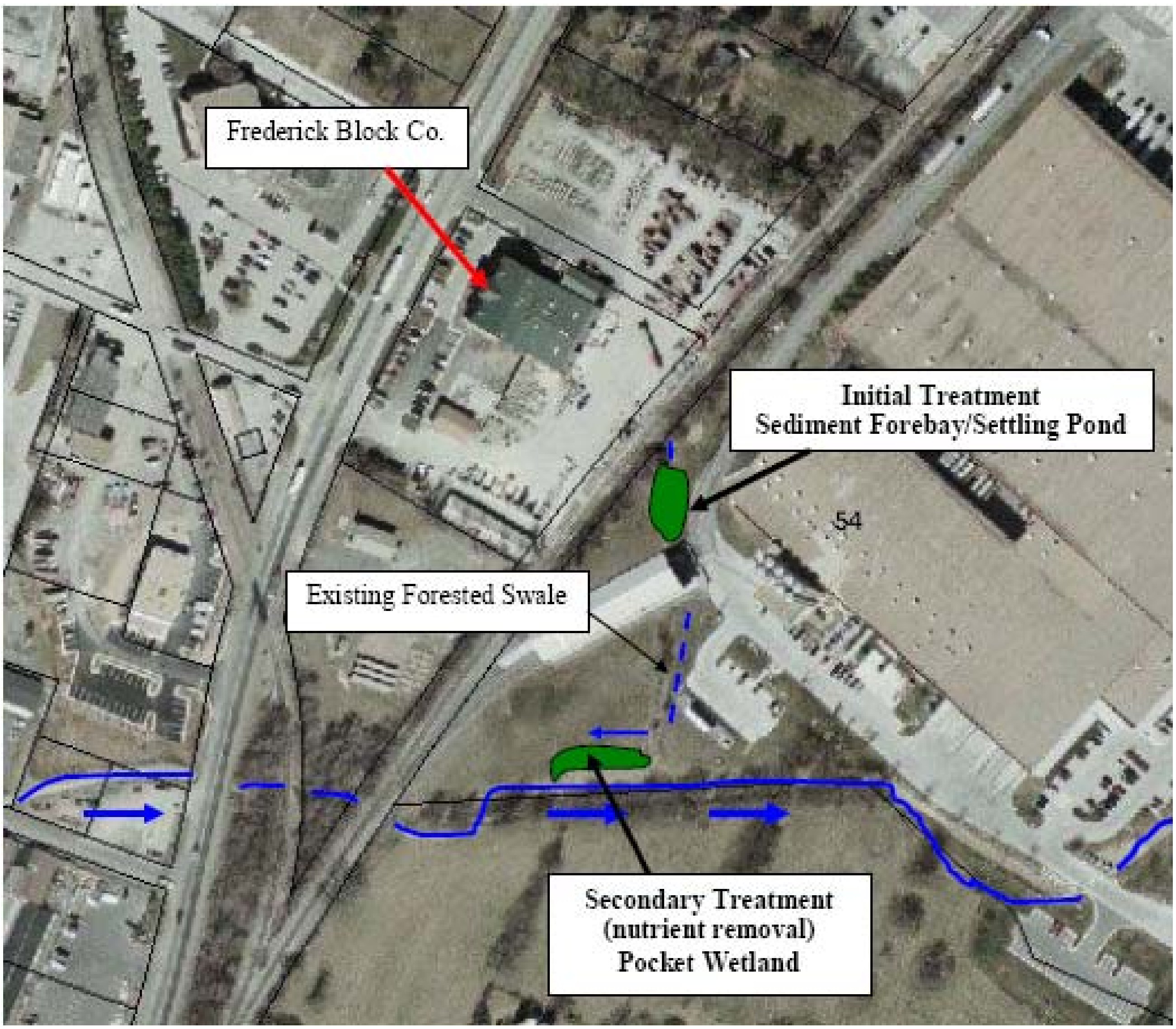

Figure A.5. Sunnyside Run floodplain wetland site location

Located further downstream between the Delco-Remy and Kingsdowne facilities, a floodplain wetland was installed to treat over bank storm flows. This project compliments a series of community tree plantings and general floodplain restoration efforts that have been implemented over the last two years.

The floodplain wetland project is designed to treat nutrients and other pollutants during storm flow conditions when most of these pollutants enter the stream. The project consists of a series of three micro pools with an inlet to draw water from Sunnyside Run at high flows. The third (downstream) micro pool contains a vegetated level spreader which sheet flows to an existing reforested swale leading back to the main channel. Native wetland plants, grasses and shrubs were planted to provide nutrient uptake.

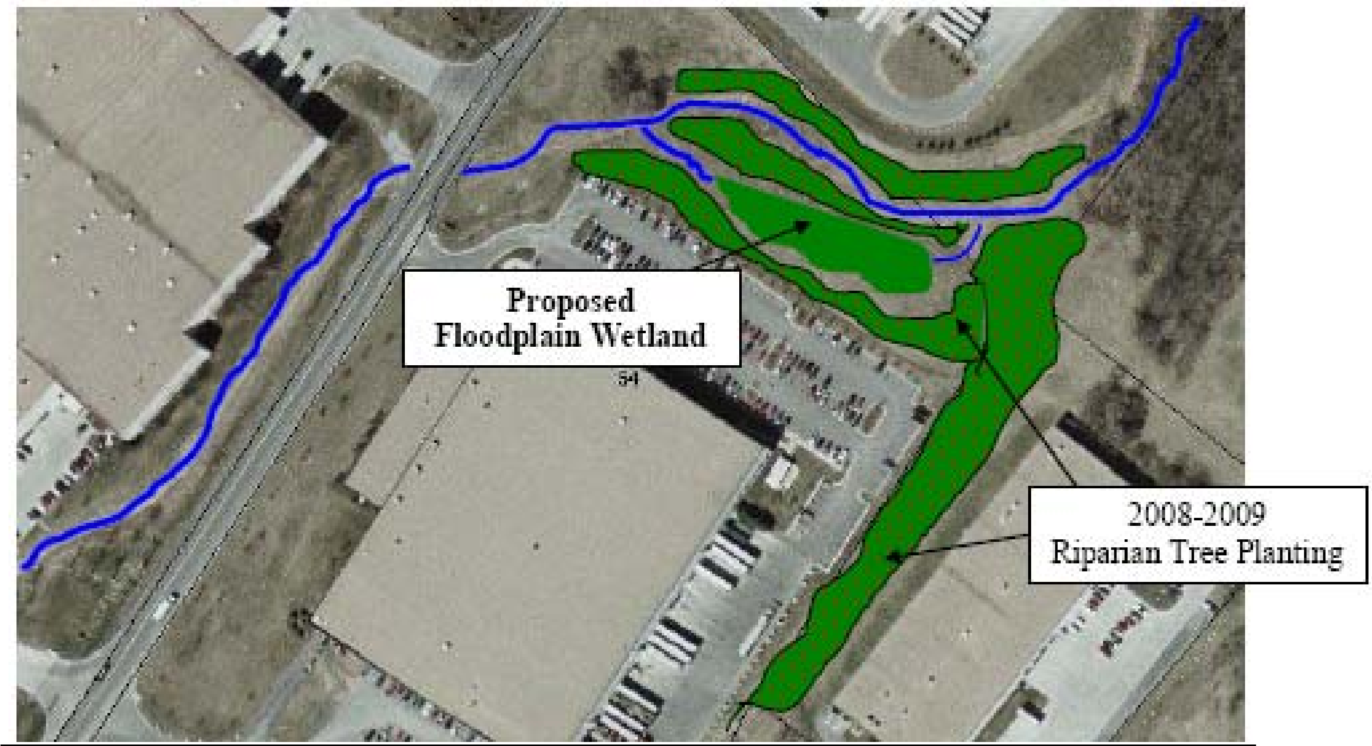

Figure A.6. Sunnyside Run floodplain wetland layout.

C) Delco-Remy Water Grass Channel/Bioretention Retrofit Demonstration

This project treats runoff from the facility's 1.78 acre parking lot and is the most important in terms of a retrofit demonstration. Following preliminary design work the original proposal called for the existing grass channel to be converted to a series of water quality swales. However this approach was determined to be insufficient in terms of handling the runoff reduction goals in the new VA stormwater guidelines (approved in late 2009 by the state water control board). The project was redesigned using three biorentention units instead. This new design demonstrates how innovative practices can be retrofitted into existing systems without costly diversions. The existing grass channel was not disturbed and served as the method of conveyance during construction. It was incorporated into the design and utilized as a conduit to handle overflow from the new practices. In hindsight this new design will do far more to address barriers to implementation of stormwater BMPs than the original proposal. Most notably it has greatly reduced the potential for erosion and sediment control problems during construction and prior to the full establishment of vegetative cover in the post construction phase as well.

Drainage from Delco-Remy Parking Lot to Grass Channel

Ponding at curb cuts

Erosion at curb cuts

Figure A.7. Retrofit demonstration for problem drainageway

Original proposal showing locations of the additional bioretention cells

Delco-Remy Water Quality Swale Retrofit

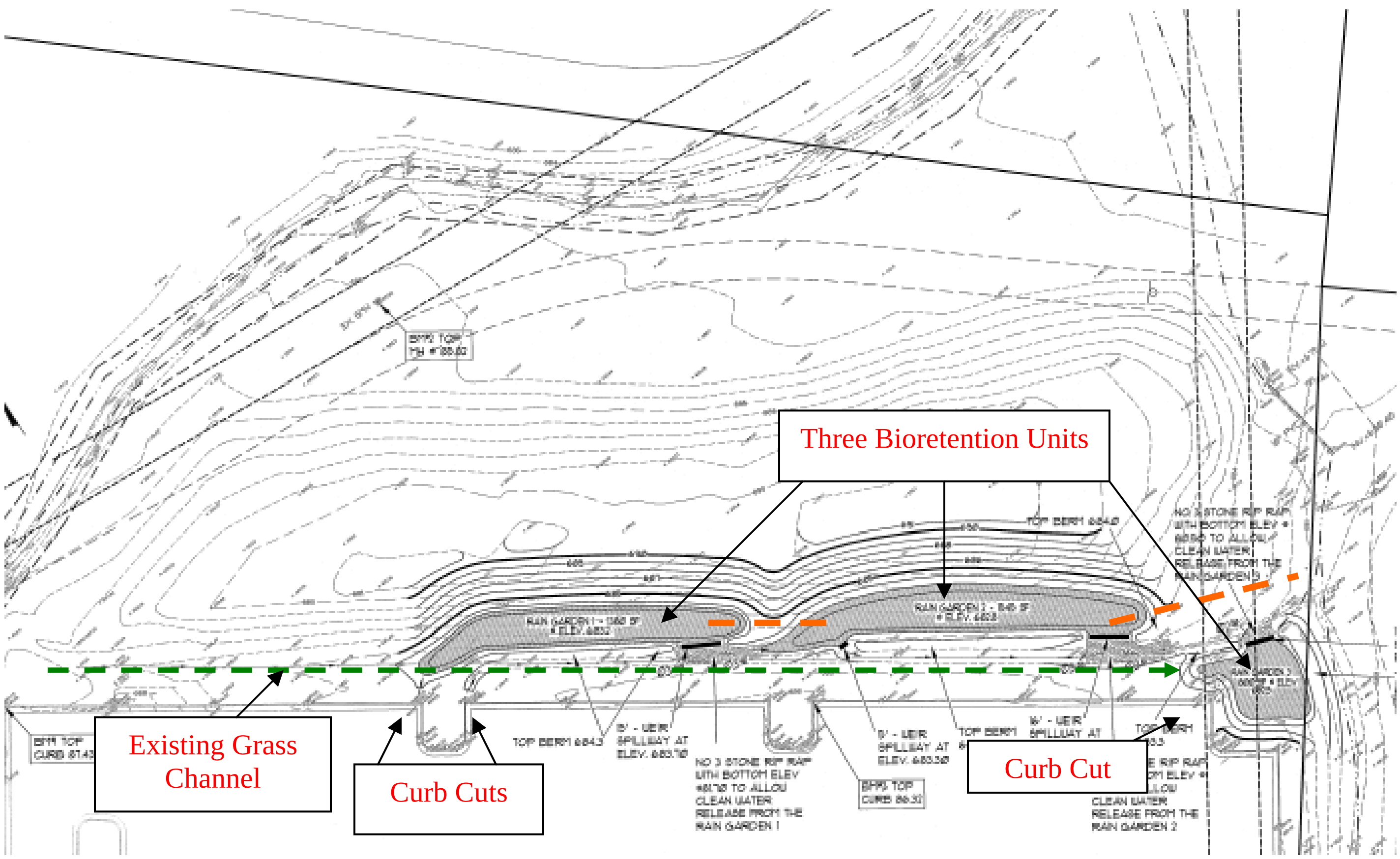

Figure A.8. Grass Channel/Bioretention Retrofit Demonstration

Deliverables/Milestones

Overall, these projects demonstrate solutions to three major impacts streams are subjected to in urbanizing areas: sediment loading from specific areas, runoff from large parking lots and industrial roofs, and instream erosion from a lack of riparian buffers or adequate floodplain areas. All these problems are addressed along a quarter mile section of Sunnyside Run.

The Upper Sunnyside Run-Enhanced Sediment Forebays and Pocket Wetland are the first steps of a concerted effort by Southeastern Container Inc. to address the facility's stormwater management issues. Follow-up projects include bioretention retrofits for two parking areas, a review of the current turf management policies and interest in utilizing the *Stormwater Benchmarking Tool* developed by the Chesapeake Stormwater Network. Installation of the practices has made a dramatic effect on the sediment loads delivered to Sunnyside Run and has created interest among other tenants in the industrial park as well as businesses upstream. Stormwater BMPs and especially small connected practices are quite uncommon for the area and the owners are willing to host workshops and tours to raise awareness about these practices and the resources they protect locally downstream.

Specific to the Delco-Remy facility are three approaches to different sources of stormwater runoff. Floodplain restoration and the creation of micro pools for extended detention and treatment of excessive storm volumes in Sunnyside Run decreases instream erosion. The planting of trees and shrubs and establishment of no-mow zones in managed turf and grass channels will decrease runoff velocity, improve filtration and increase groundwater recharge. The additional bioretention units will filter the first flush from the 1.78 acre parking lot and provide storage to further reduce runoff. New stormwater rules and regulations alone will not significantly improve water quality in developed areas. Retrofitting will have to be a major part of an overall strategy to lessen the impacts from stormwater. A 24" x 36" pedestal style interpretive panel describing the environmental benefits of the practices will be installed at the Delco-Remy facility.

These projects also deal with the specific barriers to implementation of innovative stormwater practices. Most importantly the additional bioretention units demonstrate the ability to utilize an existing system (the grass channel) when retrofitting thus avoiding costly diversions and erosion and sediment control challenges during construction. Other barriers include, unknown maintenance costs and guidelines and a general lack of understanding regarding the benefits of natural systems and a fear that they will not be aesthetically pleasing. This suite of demonstrations and the willingness of the owner and corporate tenants to promote them will help to overcome those barriers and false perceptions as well.

Outcomes

These demonstration projects will raise awareness among citizens and local decision makers alike about the critical role that stormwater management plays in protecting a unique local resource (the Redbud Run Greenway and trout fishery). The water quality challenge for Redbud has always been lessening the stormwater impacts from the upper two-thirds of the watershed. That is why the stormwater projects and tree plantings in the Fort Collier industrial park are so important. Redbud Run is a tangible example for the local decision makers of why it is necessary to focus on the water quality aspects of stormwater management. Simply stated, the Redbud Run Greenway serves as the region's Chesapeake Bay.

The Fort Collier Industrial Park stormwater management retrofit projects were featured in an article in the winter 2010 issue of Trout Magazine which is the national publication of Trout Unlimited.

Project Team and Resources

The Virginia Department of Environmental Quality provided $28,430 in Supplemental Environmental Project funding to the Lord Fairfax Soil & Water Conservation District for the Fort Collier stormwater projects. The Opequon Watershed, Inc. (TOW) received $22,330 in reimbursement grants from the Regional Water Quality Improvement Fund administered by the Virginia Departments of Forestry and Conservation & Recreation. TOW also served as the fiscal agent for the reimbursement grants and procured a $32,000 low interest community loan from a local bank to meet the cash flow needs. Overall project coordination was provided by the watershed coordinator of the Opequon Targeted Watershed Project which also provided $10,415 towards construction costs. Most importantly Whitney Wagner (owner/manager) of Fort Collier LC has been extremely supportive by successfully promoting these projects and other initiatives as well with his corporate tenants

Reference:

Heatwole, C.D., J. Lawrence, W.C. Hession, A. Ludwig. 2010. Opequon targeted watershed project final report – Appendix A: Innovative stormwater management practices. Biological Systems Engineering, Virginia Tech, Blacksburg.

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