Ecosystem-Based Management Pilot

The Upper Susquehanna Coalition Conservation Buffer Initiative

The Upper Susquehanna Coalition of 16 Soil and Water Conservation Districts that encompass the headwaters to the Chesapeake Bay have piloted a conservation buffer initiative using the Agricultural Environmental Management program to integrate a basin-wide buffer approach. Under this initiative the Upper Susquehanna Coalition mapped the watershed to identify areas that have the potential to maximize buffer effectiveness, implemented buffer projects on 29 farms, and developed the staffing infrastructure to facilitate a watershed approach to grazing and buffer implementation.

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The Upper Susquehanna Coalition Conservation Buffer Initiative combines all buffer types, cow exclusion practices, prescribed grazing, and supporting practices to address both agricultural sustainability and community needs in relation to stream bank erosion, habitat improvement, and flooding.

Ecosystem Based Management Pilot
The Upper Susquehanna Coalition
Conservation Buffer Initiative

PROJECT DESCRIPTION

Nutrient and sediment loading are the major water quality issues in the Susquehanna River Headwater upstream of Towanda, PA. Their sources are from flashy and unstable streams, frequent flooding events, improper road maintenance and agricultural runoff mainly from dairy farms.

This project advanced the need to maintain the integrity of stream corridors in the Upper Susquehanna Basin to process nutrients and mitigate agricultural runoff and erosion. The project was coordinated by the Upper Susquehanna coalition (USC) of Soil and Water Conservation Districts that encompass the headwaters of the Susquehanna River and Chesapeake Bay. The Coalition works under a Memorandum of Understanding based on NY Soil and Water Conservation District Law allowing Districts to enter into multi-district agreements.

The USC has integrated efforts over the watershed through three "implementation focus areas": 1) buffers, 2) streams and 3) wetlands. Cornell University has supported this effort by locating "hydrologically sensitive areas" (HSAs) through the Soil Moisture Routing Model. HSAs are those small portions of a watershed that account for a disproportionately large fraction of storm runoff. The USC used these HSAs locations as a tool to identify potential high priority implementation sites where we could to construct wetlands, rehabilitate streams, install riparian buffers and implement prescribed grazing (e.g., wall to wall buffers).

The USC considers the enhancement of stream corridor management an important goal. Favored methods include controlled and limited livestock access to surface water through animal behavior management, exclusionary fencing, or establishment of buffers. The USC Districts have used the AEM tiered approach to farm planning to educate producers and address the importance of livestock exclusion and maintaining water quality and healthy riparian areas.

Project Objectives and Tasks

Conservation Buffers help to filter pollutants, provide fish and wildlife habitat, improve water quality, stabilize streambanks, attenuate surface runoff and overall contribute to a healthy watershed. Examples of conservation buffers include filter strips, grassed waterways, forested and grassed riparian streambanks, contour strips, and wetlands. In pastures with streams, livestock exclusion with permanent fencing buffers streambanks. Indeed prescribed grazing systems, which provide high quality permanent forage can be considered "wall to wall" buffers in terms of riparian protection due to their ability to minimize overland flow and trap sediment and nutrients.

Conservation buffers are a core conservation practice recognized under the New York State AEM (Agricultural Environmental Management) program and several United States Department of Agriculture (USDA) Farm Bill Programs. AEM is a voluntary, incentive-based program that helps farmers operate environmentally sound and economically viable businesses. Farmers utilize AEM to address water quality concerns originating from agricultural activity by planning, implementing and evaluating conservation systems.

The USC is deeply involved in establishing buffers of all types to address nutrient reductions, water quality improvement, habitat protection and enhancement and wildlife diversity. In 2009 the USC started a program that combines "buffer related" projects into an umbrella approach we call the USC Grazing Initiative: it combines all buffer types, cow exclusion practices, prescribed grazing, and supporting practices to address both agricultural sustainability and community needs in relation to streambank erosion, habitat improvement and flooding. Furthermore, the Initiative complements the USC Wetland Program adding further value to both programs.

The objective of this project was to pilot a New York State Conservation Buffer Initiative in the Upper Susquehanna Basin. Using the AEM framework as the foundation to our approach, the following tasks guided our implementation:

Task 1:
Develop an Integrated Buffer Approach

1) Develop list of buffer types (i.e., riparian, swales, wetlands) and potential funding sources to support installation
2) Map the watershed to understand where buffer potential exists, where programs are available and where expertise is currently located
3) Expand upon the "variable source hydrology" concept as a key feature of buffer establishment using concepts gleaned from "A new paradigm for sizing riparian buffers to reduce risks of polluted storm water: A practical synthesis, Archibald et al., Cornell
4) Develop leverage protocols (how can the USC combine two or more funding sources/programs to develop a working buffer project)
5) Develop a methodology to integrate buffers, cow exclusion and prescribed grazing to maximize the potential implementation for all three components
6) Develop sufficient staffing infrastructure, including a point person (coordinator) to facilitate a watershed approach
7) Develop a working map that locates buffer needs and opportunities based Basin Plans already developed (NY Tributary Strategy, AEM County Strategies, NY Chesapeake Bay Tributary Strategy, WRAPS)

Task 2:
Implementation of Conservation Buffer Systems on Farms

1) Conservation Buffer Systems will be designed and installed on at least twenty Upper Susquehanna Basin farms in the New York portion of the basin. Cost share assistance will be mated with the Federal Farm Bill Conservation Reserve Enhancement Program (CREP) funding to demonstrate the leveraging potential that exists when programs are combined.
2) All Buffer Systems and complimentary practices will be installed according to federal technical standards from the USDA Natural Resources Conservation Service. Consistent with a systems approach, AEM Tier 3a Resource Management Plans will be required for the entire farm. Upland treatment to maintain buffer integrity will be implemented for specific project sites.

Task 3:
Develop a Sustainable Approach

1) The Upper Susquehanna Coalition will seek additional grant funding to develop a Grass-Based Initiative that will integrate buffers with livestock exclusion and prescribed grazing.

Summary of Work Completed

Task 1: Develop an Integrated Buffer Approach
1) Develop a list of buffer types and potential funding sources to support installation:

In the spring of 2012 the New York State (NYS) Department of Environmental Conservation (DEC), in collaboration with NYS Department of Agriculture and Markets and the Upper Susquehanna Coalition submitted the Draft Phase II Watershed Implementation Plan (WIP II) to the Environmental Protection Agency's (EPA) Chesapeake Bay Program (CBP) (http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/PhaseIIWIPS/NYWIPPhase2Final3_23_12.pdf). Section 3 of this plan identifies several types of buffers and funding sources to support implementation. The types of buffers include animal exclusion, vegetated open channel grass buffers, forest buffers, degraded riparian pasture buffers, and wetland buffers. Predicted future funding sources include CBP Implementation Agreement, USDA Farm Bill programs, NYS Agricultural Environmental Management Program, NYS Ag Nonpoint Source Abatement and Control Grant Program, National Fish and Wildlife Foundation Small Watersheds Grant and Innovative Nutrient and Sediment Reduction Program, and farmer contributions.

2-3) Map the watershed to understand where buffer potential exists and expand upon the "variable source hydrology" concept:

See appendix "A" for a copy of the complete report. The following is an executive summary:

In the northeastern US a relatively small portion of the landscape generates a disproportionately large percentage of its storm runoff. Protecting these runoff-prone areas, referred to as hydrologically

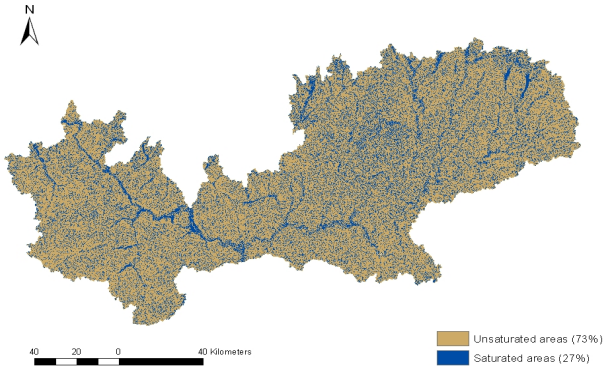

Figure 1. A composite HSA map for the USRB for the 1-yr return period based on the average of 9 sub-watersheds. Unsaturated areas are lighter color and make up 73% of the area. Saturated areas are darker and make up 27%.

sensitive areas (HSAs) from potentially polluting activities is an effective strategy for reducing nonpoint source (NPS) phosphorus pollution. Conceptually, we recognize that these are areas where soils are effectively prone to saturate such as areas of topographic convergence, the toe-slopes of hillsides, and soils underlain with a shallow layer of low permeability. For making land management decisions we need a way to reliably quantify the runoff risk associated across the Upper Susquehanna River Basin (USRB). We developed a method that accounted for both rainfall magnitude and antecedent wetness conditions to map runoff prone areas for any risk level (Figure 1). We applied this HSA-mapping methodology to nine sub-watersheds within the USRB where sufficient stream discharge and rainfall data were available. There were some inherent differences in the HSA risks among the nine basins, most of which we cannot yet explain. The exception is for watersheds with notable urbanized areas, which resulted in higher HSA-risks. To generalize our findings to the entire USRB, including un-gauged sub-watersheds, we used an average risk function based on the eight basins without substantial urban development. We have included land characteristics and risk functions for each watershed so that the method can be tailored to specific un-gauged watersheds if necessary, i.e., one can choose the risk function associated with one of our nine watersheds that appears to be the most similar to a specific un-gauged watershed. The base maps and final analyses are available in ArcGIS format.

4) Develop leverage protocols outlining a multiple funded approach to install buffer practices on farms:

This grant provided support for the USC Ag Team, whose structure and function are to be described in Section 6 below. The Ag Team began the pilot by selecting 29 farms active in the AEM process that required integration with funding from federal Farm Bill Programs and other local, state, and federal initiatives to develop a working buffer project. The Team used a variety of tools to select the farms including the variable source hydrology concept and/or using a request form created by the Ag Team to prioritize a list of projects. The Team reviewed the requests and ranked them based on location, animal numbers, acres of implementation, ability to continue the practices, availability to leverage other funds and other factors as appropriate (Appendix B).

EBM/USC funding was essential in implementing buffer projects that wouldn't have been funded otherwise by helping to fill in niches and adding that one component not covered by conventional funding sources. We have found that providing a relatively small component of a larger project was key to getting it implemented. There are many programs available to help implement BMPs but each has its own set of rules. Combining several sources of funds and adding farmer match often moves a project forward when it would have otherwise been abandoned. For example, farmers would have federal and/or state funding to install animal exclusion or buffer projects, but there weren't financial resources to pay for the necessary alternative watering facilities or stream crossings. The USC was able to provide additional funds that then allowed the farmer to implement the exclusion/buffer project. Without the EBM/USC funds, the project wouldn't have happened or would have taken longer to accomplish.

5) Develop a methodology to integrate buffers, cow exclusion and prescribed grazing to maximize the potential implementation for all three components:

See the next section below for a combined description of our methodology and infrastructure.

6) Develop sufficient staffing infrastructure, including a point person (coordinator) to facilitate a watershed approach.

The USC has a strong culture of grazing/buffer implementation in the watershed. We have developed three overlapping focus areas, or "teams", to implement conservation on the local level: Agriculture,

Wetlands, and Streams. Each area has a regional coordinator and a local team of technical experts to implement projects, provide outreach to stakeholders, increase capacity of other technicians, and to provide data for reporting. Specifically, the Agricultural Team has a Team Leader, a Coordinator, two Grazing Specialists, a GIS specialist, lead Data Collectors, and Technicians. This team was supported in 2009 with the help of the NFWF CB Stewardship Fund and Ecosystem Based Management Pilot. With the help of these grants, the USC launched its Grazing Initiative. This program's priority is to create "wall to wall buffers" by first focusing on fencing cattle from streams, as it is often the first step for farmers in our area who want to implement prescribed grazing. The livestock exclusion measures eliminate direct nutrient loading from cow manure and protect stream banks from destabilization through trampling. The associated practices that go with buffers such as fencing, stream crossings, and alternative watering systems, often support a prescribed grazing system that function as a much larger buffer. When row crops and marginal areas are replaced by high quality pasture, native grasses, and trees, negative impacts to water quality are minimized by the reducing runoff and improving nutrient distribution and utilization. In addition, the potential to create beneficial habitat for fish and wildlife are maximized.

With this project we saw how having a coordinated approach with a team of Ag experts maximizes implementation in the region due to the ability to identify priorities and needs on a larger scale, and having the network of communication to allocate resources in response. Another strength of the USC Grazing Initiative is our ability to coordinate work with the NYS versions of federal programs such as CRP/CREP, EQIP/CBWI and others, especially now that all NY Chesapeake Bay watersheds have become CRP/CREP eligible (Appendix C). A third strength was the use of District equipment, tools, and supplies to build or repair small sections of fence on farms as we found it can be the stimulus for a farmer to begin trying additional grazing practices. It is also a good marketing approach as working together with a farmer to build or repair a fence provides the opportunity to discuss more intensive precision grazing methods with them while the technician is out there.

In sum, the USC approach provides for a coordinated, consistent, and sustainable method to implement grazing and buffer projects in the region.

7) Develop a working map that locates buffer needs and opportunities based on Basin Plans already developed:

In the spring of 2012 the New York State (NYS) Department of Environmental Conservation (DEC), in

Table 1. List of Ag BMPs, the current and target implementation levels according to CBP Watershed Model v.5.3.2.

Practice	Available Units FROM MODEL	Current Status FROM MODEL	WIP 2 Implementaion Levels
Animal Waste Management	1,000 dairy farms	NA	**95,400 AU**
BarnYard Runoff Control Systems	1,000 dairy farms	155 ac	**750 ac**
Precision Feeding Dairy	1,000 dairy farms	4,800 A.U.	**49,500 AU**
Mortality Composters	1,000 dairy farms	NA	**80% of Mortalities**
Comprehensive Nutrient Management Planning (Crop)	479,241 ac	~ 110,00 ac	**238,000 ac**
Nutrient Management	479,241 ac		**37,500 ac**
Decision Ag	479,241 ac		**77,200 ac**
Conservation Plans	811,00 ac	59,716 ac	**465,325 ac**
Liquid Manure Injection	811,000 ac	NA	**104,051 ac**
Cover Crops (SDR) (corn)	70,000 ac	1,600 ac	**34,000ac**
Conservation-Tillage	152,678 ac	8,000 ac	**51,000 ac**
Continuous No-Till	152,678 ac	529 ac	**1,362 ac**
Prescribed Grazing / PIRG	182,000 ac	33,000 ac	**108,745 ac**
Alternative Watering Facility (Off-Stream Watering w/ No Fencing)	182,000 ac	580 ac	**8,830 ac**
Pastfence/StreamAccessControl W/Fencing (convert from trp to pasture)	12,000 ac	1,280 ac	**5,050 ac**
Forest Buffers	811,00 ac	3,874 ac	**6,000 ac**
Grass Buffers	811,000 ac	6,863 ac	**9,800 ac**
Land Retirement	811,00 ac	7,585 ac	**8,530 ac**
Tree Planting	811,000 ac	1,780	**1,915 ac**
Non Urban Stream Restoration	811,00 ac	NA	**397,500 ac**
Wetland Restoration	811,000 ac	5,743 ac	**11,124 ac**

collaboration with NYS Department of Agriculture and Markets and the Upper Susquehanna Coalition (USC) submitted the Draft Phase II Watershed Implementation Plan (WIP II) to the Environmental Protection Agency's (EPA) Chesapeake Bay Program (CBP) (http://www.dec.ny.gov/docs/water_pdf/finalphaseiwip.pdf). Section 3 of this plan identifies several types of buffers and funding sources to support implementation. The WIP II is the plan that the USC Districts are using to guide implementation efforts. This plan will change as we attempt to meet TMDL targets by monitoring our progress, setting 2-year milestone goals, and modifying our levels based on implementation success and the funding.

Under the TMDL, specific location of a BMP is not as important as the total level of implementation. Table 1 gives a list of Ag BMPs, our current level of implementation and the 2025 TMDL target implementation goal identified in WIP II based on watershed needs and opportunities. These BMPs, which include Buffer and related Grazing practices, were given cumulative target totals based on basin-wide implementation. Therefore the USC's approach under the TMDL is focused on an aggregated total. However, there are priority areas identified by conservation funding agencies like the NRCS and the National Fish and Wildlife Foundation. Therefore implementation will focus on those areas throughout the duration of the TMDL (Figures 2, 3). In addition, the Cornell analysis of at risk streambanks will provide for another informational layer we will use as project funding becomes available (Figure 4).

In 2011 and 2012 two buffer related proposals were submitted. The first was a 5-year, $2.2M request to the NYS Ag and Markets to fund a special project in the NY Susquehanna watershed to support a cattle exclusion/buffers/grazing program. The second was a 3-year, $200,000 proposal to NFWF's Stewardship Fund to continue build upon the successes of the EBM grant. Additional proposals will be submitted in

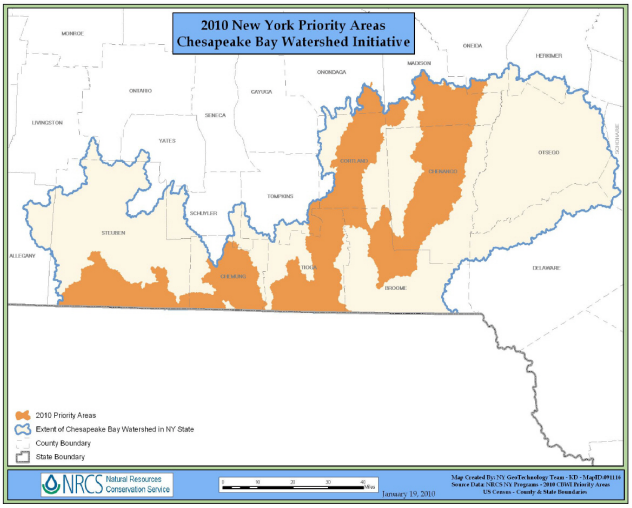

Figure 2. Priority areas identified by the Natural Resources Conservation Service.

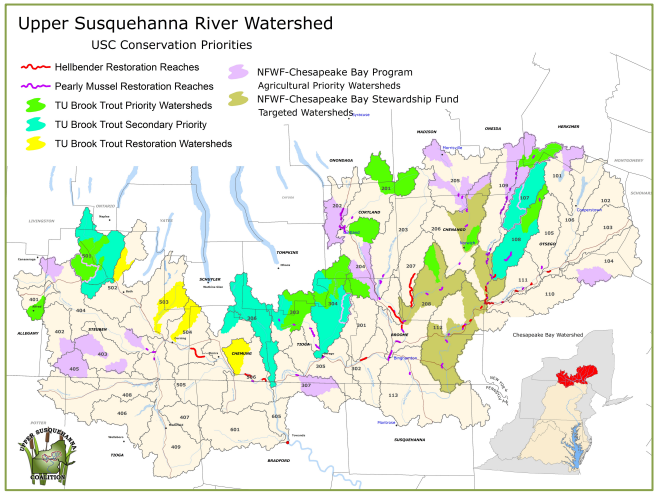

Figure 3. Priority areas identified by the National Fish and Wildlife Foundation.

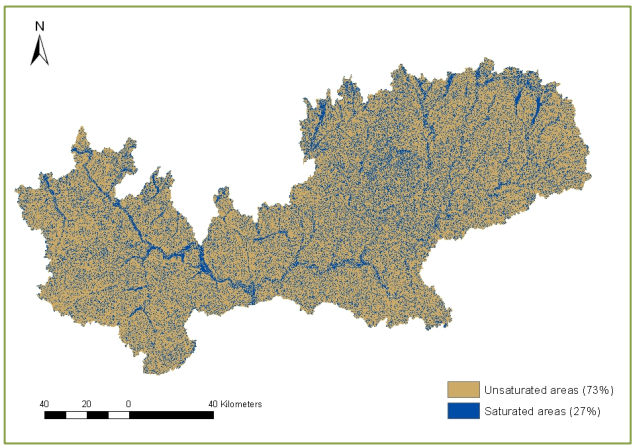

Figure 4. Priority areas identified by applying HSA-mapping methodology

the future, as these proposals were not successful. There will be more details on the two proposals in a later section.

Task 2: Implementation of Conservation Buffer Systems on Farms

Design and Install Conservation Buffer Systems on at least 20 Upper Susquehanna Basin farms in the New York portion of the Chesapeake Bay watershed.

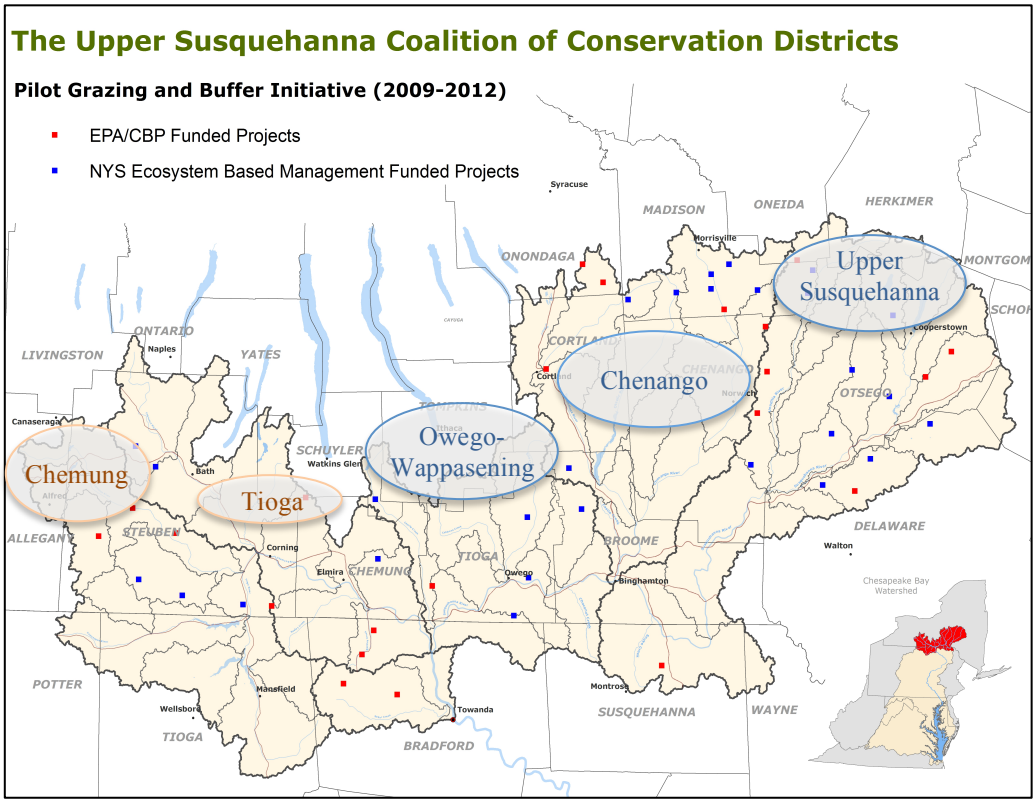

Figure 5. Map showing distribution of buffer projects throughout 5 major watersheds. 29 of 50 projects were funded by EBM that was used as match for a EPA/CBP grant.

This project demonstrates how our locally based, regional approach integrating both state and federal funds is a highly efficient and effective way to maximize water quality conservation efforts (Figure 5 –watershed map). Our approach is targeted, flexible, and innovative. Based on prioritized needs, we use the Agricultural Environmental Management planning process to maximize potential load reductions through high quality management practices such as buffers and grazing. When possible, we combine various funding sources to get conservation practices on the ground.

In September of 2010, USC Agricultural Team members selected 20 farms that had practices such as support for rotational grazing, animal exclusion, stream crossings, buffers, wetland protection, and alternative water supply. All Buffer Systems and complimentary practices were installed according to federal technical standards from the USDA NRCS and all projects completed a Conservation Reserve Enhancement Program (CREP) Site Condition Evaluation and Environmental Benefits Report (Appendix D). Most projects were implemented at sites leveraged with the federal Farm Bill programs such as CRP/CREP and demonstrated the leveraging potential that exists when programs are combined. This project is supporting the development of a sustainable approach through a coordinated effort of state and federal programs using AEM as the foundation of implementation. As projects were completed, sufficient funds remained in the project to include an additional 9 farms in the project for a total of 29 farms.

Table 2 is the total summation of the 29 projects implementing buffers and supporting practices throughout the entire Susquehanna-Chemung basin. The table highlights all of the work the

Table 2. Summary of the 29 projects implementing buffers and supporting practices throughout the entire Susquehanna-Chemung basin.

	29 Farms in CB Headwaters		
Practice	**EBM**	**Leveraged**	**Total**
Riparian Buffer (Ac)	93.7	134.1	**227.8**
Wetland Exclusion (Ac)	7.7	42.2	**49.9**
New Prescribed Grazing Established (Ac)	160.9	43.5	**204.4**
Stream Crossings (#)	4	5	**9.0**
Alternative Water Supply (#)	10	9	**19.0**

Conservation Districts and their cooperators completed: 227.8 acres of riparian buffers, 49.9 acres of wetland exclusion, 204.4 acres of new grazing, 9 stream crossings and 19 alternative watering systems installed. The total cost of the EBM grants was $222,500 on 29 farms, or an average of $7,672.41 per farm over a 2.5-year period. Using this success as an example, in 5 years and $1M, the USC could affect 100 farms, improve water quality across the entire region, and make a heavy dent toward WIP II goals. As impressive as these numbers are as a group, it is still important to break the projects out to tell individual stories of how the USC Grazing Initiative is working on the ground.

The Chemung and Susquehanna rivers combine just south of the NY border to make up the Upper Susquehanna River. These two major systems can be broken into five major sub-watersheds that include from east to west: the Upper Susquehanna, the Chenango, the Owego-Wappasening, the Tioga, and the Chemung Rivers (Figure 5). To facilitate reporting, the 29 farm projects have been grouped into one of the 5 major watersheds. See Table 3 on page 11 for a summary of implementation broken down into sub-watershed and farm. A descriptive summary of sub-watershed implementation and highlights are described below beginning on page 12.

Table 3. Summary of buffer implementation with supporting practices by sub-watershed and farm.

Cooperator AEM #	Major Watershed	Sub Watershed	New Buffer (Ac)	Leveraged New Buffer (Ac)	Wetland Exclusion (Ac)	Leveraged Wetland Exclusion (Ac)	New Grazing (Ac)	Leveraged New Grazing (Ac)	# of New Stream Crossings	Leveraged New Stream Crossings	# of Alternative Water Systems	Leveraged Alternative Water	Project Leveraged
Upper Susquehanna River Watershed													
025-0528	Upper Susquehanna	Carr's Creek	9.6	-	-	-	-	-	-	1	-	1	Leveraged CREP for buffer,water supply system and tree planting
025-0061	Upper Susquehanna	Charlotte Creek	-	-	-	10.0	-	-	-	-	-	-	Leveraged CRP; USC paid for the installation of water supply
025-0518	Upper Susquehanna	Ouleout	-	4.0	-	-	-	16.5	-	-	-	1	Leveraged Rd 15 ANPSACP; Access Lane for PRG System
017-0323	Upper Susquehanna	Unadilla	-	69.7	-	-	9.3	-	-	2	-	1	Leveraged CRP for riparian forest buffer, waterline, 6 troughs, 2 crossings, 1pond
053-0335	Upper Susquehanna	Unadilla	2.3	-	-	-	-	-	1	-	1	-	USC funded project
053-0322	Upper Susquehanna	Unadilla	2.2	-	-	-	-	-	1	-	1	-	Leveraged EQIP for spring development, waterline, hydrants, fencing
077-0158	Upper Susquehanna	Upper Unadilla	-	6.1	-	-	-	-	1	-	-	-	Leveraged CRP and EQIP for riparian forest buffer, crossing, laneway
077-0417	Upper Susquehanna	Oaks Creek	0.4	0.9	-	-	-	-	-	-	-	-	Leverage 0.9 acres of CREP riparian buffer
077-0434	Upper Susquehanna	Upper Schenevus Creek	-	15.6	-	1.0	-	-	1	-	-	-	Leveraged CRP; buffer; laneways; tree planting, 1 crossing
077-0448	Upper Susquehanna	Upper Otego Creek	-	1.6	-	-	-	-	-	-	1	-	Leveraging CREP for riparian forest buffer
077-0449	Upper Susquehanna	Otego/Butternut Creek	-	-	5.5	-	-	-	-	-	-	-	USC funded project
		Sub Total:	**14.5**	**97.9**	**5.5**	**11.0**	**9.3**	**16.5**	**4.0**	**3.0**	**3.0**	**3.0**	
Chenango River Watershed													
053-0165	Chenango	Chenango	1.0	1.1	-	-	-	-	-	1	-	1	Leveraged local source for fencing, watering system and stream crossing
053-0169	Chenango	Chenango	1.5	-	-	-	-	-	-	-	1	-	USC funded project
053-0199	Chenango	Chenango	4.0	-	-	-	-	-	-	-	-	-	USC funded project
053-0256	Chenango	Chenango/Sangerfield	2.0	2.0	-	-	17.0	-	-	-	1	-	NRCS Contribution Agreement, FLLOWPA
053-0051	Chenango	Otselic	17.0	-	-	-	15.0	-	-	-	-	-	Leverage riparian buffer with DEC Trees for Tribs program
053-0003	Chenango	Tioughnioga	-	-	1.0	-	-	-	-	-	1	1	NRCS Contribution Agreement; ANPSACP Round 13
007-0098	Chenango	Lower Tioughnioga	0.6	22.0	-	-	-	-	-	-	-	-	Leveraged GRP, CRP and EPF state dollars
		Sub Total:	**26.1**	**25.1**	**1.0**	**0.0**	**32.0**	**0.0**	**0.0**	**1.0**	**3.0**	**2.0**	
Owego-Wappasening Watershed													
097-1406	Owego-Wappasening	Headwaters Cayuta Creek	-	-	1.3	-	13.0	-	-	-	1	-	USC funded project
007-0099	Owego-Wappasening	Nanticoke Creek	1.5	3.5	-	-	-	-	-	-	-	-	Leveraged EQIP for more buffer
107-0013	Owego-Wappasening	Little Nanticoke	-	4.5	-	-	-	-	-	-	-	-	Leverage 4.5 acres of buffer with CREP
107-0017	Owego-Wappasening	Lower East Branch Owego Creek	10.4	-	-	-	78.0	27.0	-	1	-	2	Leveraged CREP for riparian buffer, new silvopasture, waterline, crossing
107-0029	Owego-Wappasening	Middle Wappasening Creek	2.0	-	-	31.2	-	-	-	-	-	-	Leveraged CRP for wetland buffer
		Sub Total:	**13.9**	**8.0**	**1.3**	**31.2**	**91.0**	**27.0**	**0.0**	**1.0**	**1.0**	**2.0**	
Tioga River Watershed													
101-0886	Tioga	Tuscarora Creek	3.5	-	-	-	-	-	-	-	1	-	USC funded project
		Sub Total:	**3.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.0**	**0.0**	
Chemung River Watershed													
015-0096	Chemung	Baldwin Creek	0.5	3.1	-	-	13.6	-	-	-	1	-	Leveraged CBWI money for complete grazing system
101-0679	Chemung	Campbell Creek	3.7	-	-	-	7.0	-	-	-	1	-	USC funded project
101-0992	Chemung	Neils Creek	1.0	-	-	-	8.0	-	-	-	-	1	Farmer installed water on their own
101-0748	Chemung	Lower Five Mile Creek	2.9	-	-	-	-	-	-	-	-	-	USC funded project
101-0653	Chemung	Upper Cohocton	27.5	-	-	-	-	-	-	-	-	1	Leveraged ANPSACP for pond, waterline, pasture development, tile outlet
		Sub Total:	**35.6**	**3.1**	**0.0**	**0.0**	**28.6**	**0.0**	**0.0**	**0.0**	**2.0**	**2.0**	
Upper Susquehanna River Watershed Total													
		Grand Total:	**93.7**	**134.1**	**7.7**	**42.2**	**160.9**	**43.5**	**4.0**	**5.0**	**10.0**	**9.0**	

Figure 6. Buffer and rotational grazing project implemented in the Unadilla sub-watershed in Chenango County NY. Field conditions before (left) and after (right) are shown. This project combined EBM and CRP funds to install nearly 70 acres of riparian forest buffer and over 9 acres of new grazing. Infrastructure to support a buffered grazing system such as waterline and crossings were also installed.

Summary of sub-watershed projects and highlights:

Upper Susquehanna River:

In the Upper Watershed of the Susquehanna River the USC completed a total of 11 projects in 7 tributary watersheds distributed over 4 counties (Table 3). EBM funds alone contributed to the installation of 20 acres of new streamside and wetland buffers that in turn leveraged an additional 108.9 acres of streamside and wetland buffers from federal programs such as CRP/CREP and EQIP, and state funds from the Agricultural Nonpoint Source Abatement and Control Program (ANPSACP). Furthermore, combining EBM and leveraged funds, 25.8 new grazing acres were added to the watershed. We also installed 7 stream crossings and 6 alternative water systems to support the complete grazing systems.

One highlight from this region is a farm located in the Unadilla sub-watershed in Chenango County (Figure 6). Assistance was requested from the Upper Susquehanna Coalition to expand the perimeter fencing for a newly adopted grazing system. This farm was in the process of transitioning from a free-stall operation to rotationally stocking livestock on fertile fields that were once used for crop production. Funding from the Conservation Reserve Program assisted this farm in establishing riparian buffers, developing an alternative water source for the grazing system, developing two cattle crossings, and establishing a water pipeline with six troughs. The money received was used to fence and establish seven paddocks on a 9.3 acre field that was transitionally used for corn and other row crops. Through the AEM process, this farm was identified as being a good candidate for implementing a grazing system because of its considerable land base and the use of an earthen manure storage pit that was not designed or constructed to NRCS specification. The implementation of a grazing system would minimize the use of the manure storage structure during the grazing season and maximize water quality potential from the farm.

A second highlight is the 160-acre, 30 cow beef farm located in the Upper Schenevus Creek sub-watershed in Otsego County. The funds provided by the USC were used to cost-share a stream

crossing and approximately 3,350 feet of fence, excluding livestock from a 1-acre wetland and buffering 15.6 acres of stream corridor. 3.4 acres of tree plantings were also installed. Full implementation of the CRP plan will be completed next year with the development of a spring and watering facility. The practices installed also support a prescribed grazing plan on 60 acres of pasture prepared through the AEM program.

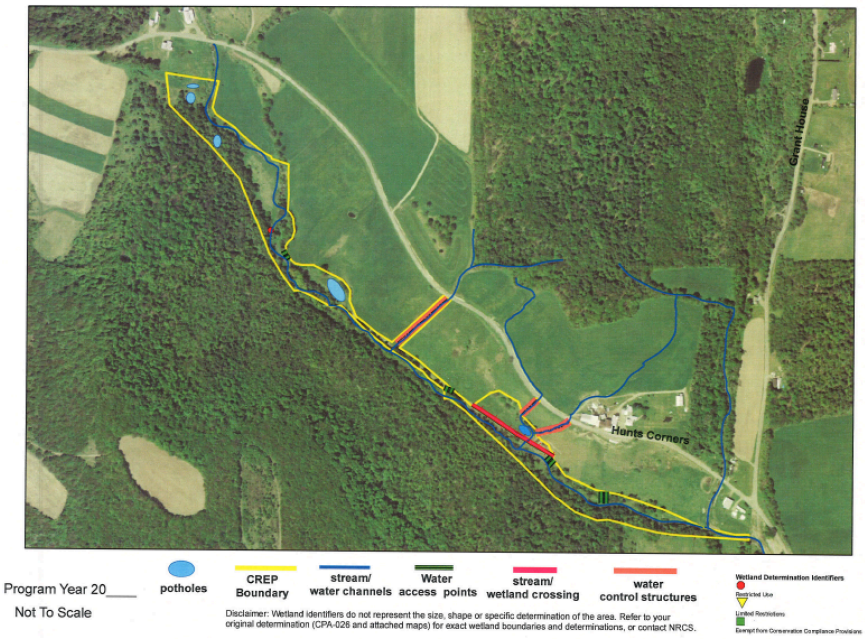

Figure 7. Grazing system planning map in the Lower Tioughnioga sub-watershed in Broome County NY.

Chenango River:

In the Chenango River watershed the USC completed a total of 7 projects in 3 tributary watersheds distributed over 2 counties. EBM funds directly contributed to the installation of 27.1 acres of new streamside and wetland buffers that in turn leveraged an additional 25.1 acres of streamside buffers from federal programs such as a USC/NRCS contribution Agreement, CRP, and the Grassland Reserve Program (GRP). In addition state funds from the Environmental Protection Fund (EPF), the Finger Lakes/Lake Ontario Watershed Protection Alliance (FLLOWPA), and the NYS Department of Environmental Conservation Trees for Tribs Program were leveraged. Combining EBM and leveraged funds, 32 new grazing acres were added to the sub-watershed. 1 stream crossing and 5 alternative water systems to support the complete grazing systems were also installed (Table 3).

One highlight from this region is a farm located in the Lower Tioughnioga sub-watershed in Broome County (Figure 7). Assistance was needed at this farm to fence dairy cattle out of the stream and create 4 potholes. The AEM planning process was used to rank this farm as a priority for the District. The Broome County SWCD, FSA, and NRCS combined resources and funding from GRP, CRP, and EPF state dollars to implement projects on this farm. In total 22.4 acres of buffer and 4 potholes were installed. Additional practices are planned for this site when funding becomes available.

A second highlight on the Chenango River is a farm located along a tributary to the Otselic sub-watershed in Madison County. This project is the primary example of what can happen when you have a buffer program in place and a cooperator eager to implement conservation (Appendix E). The challenge was simple enough – a group of relatively new farmers had purchased beef, goats and pigs and needed assistance to improve their grazing plan and restrict access of their animals to over 3,000 feet of stream. They contacted Madison SWCD for assistance in enhancing

Figure 8. Various phases of grazing/buffer implementation on a farm located along a tributary to the Otselic River in Madison County. This project included assistance from the NYS DEC Trees fro Tribs Program.

their 700-acre farm that included 80 acres of grazing land. USC Grazing Specialist, Troy Bishopp began to work with this farm to plan and coordinate implementation of the improved system. The AEM summary revealed a clear need to protect this stream from livestock and also to enhance the riparian corridor with tree plantings to provide shade to cool the waters. Troy worked hard to coordinate funding and expertise from different sources including EBM funds, NYS DEC Trees for Tribs funds and the owner's own contribution. He used local native larch and locusts posts to install 17 acres of buffer along the Otselic River that runs through the property. In addition, 2 portable water tubs and pipeline with gas powered water pump filling from the river were installed. The service provided by Troy was invaluable to both the environment and the farmer and this project could not have happened without the coordinated effort of funding and technical assistance (Figure 8).

Owego-Wappasening Watershed:

In the Owego-Wappasening watershed the USC completed a total of 5 projects in 4 tributary watersheds distributed over 3 counties (Table 3). EBM funds directly contributed to the installation of 15.2 acres of new streamside and wetland buffers that in turn leveraged an additional 39.2 acres of streamside and wetland buffers from federal programs such as CRP/CREP, and EQIP. Furthermore, combining EBM and leveraged funds, 118 new grazing acres were added to the sub-watershed. 1 stream crossing and 3 alternative water systems to support the complete grazing systems were also installed.

Figure 9. Installation of buffer fence along a tributary to Cayuta Creek in Schuyler County, NY.

A watershed highlight from this region was the Alpine Wetland project located in the headwaters of Cayuta Creek in Schuyler County (Figure 9, Appendix F). The landowner inquired with John Wickham of Schuyler County Soil and Water Conservation District and Upper Susquehanna Coalition Grazing Specialist, about the potential for installation and assistance with grazing infrastructure in order to establish a heifer operation. In addition to improving water quality, the project is helping to maintain the open space and rural character of the community. Together Tom and John worked tirelessly to install high tensile fencing according to USDA Natural Resource Conservation Service specifications. Utilizing the USC funded Soil and Water District's post pounder, over 4,600 feet of fencing equating to 1.3 acres of wetland buffer and 13 acres of new grazing was installed.

Figure 10. Installation of buffer fence along a tributary to Tuscarora Creek in Steuben County, NY.

Tioga River:

In the Tioga River watershed the USC completed a total of 1 project in the Tuscarora Creek tributary in Steuben County. EBM funds directly contributed to the installation of 3.5 acres of new streamside buffers. 1 alternative water system to support the complete grazing system was also installed (Table 3 and Figure 10).

Chemung River:

In the Chemung River watershed the USC completed a total of 5 projects in 5 tributary watersheds distributed over 2

Figure 11. Installation of a water system, stream bank stabilization, and buffer fence along a tributary to the Upper Cohocton River in Steuben County, NY

counties (Table 3). EBM funds directly contributed to the installation of 35.6 acres of new streamside buffers that in turn leveraged an additional 3.1 acres of streamside buffers from federal programs such as the Chesapeake Bay Watershed Initiative (CBWI) and the state Agricultural Nonpoint Source Abatement and Control Program. Furthermore, EBM funds added 28.6 new grazing acres to the sub-watershed. 4 alternative water systems to support the complete grazing systems were also installed.

One highlight from this region is a farm located in the Upper Cohocton sub-watershed in Steuben County (Figure 11). Assistance was requested from the Upper Susquehanna Coalition to make grazing improvements using the AEM planning process. Funding from NYS ANPSACP assisted this farm in establishing 27.5 acres of riparian buffers, developing an alternative water source for the grazing system that included a pond and water delivery system, and stabilizing the stream bank. Willows, dogwoods, and grasses were seeded. Livestock access restricted to crossing approximately 20 foot in width. Flow and water clarity improvements were visually evident.

Task 3: Develop a Sustainable Approach

1) Support coordination through the USC Grazing Initiative

The USC approach provides for a coordinated, consistent, and sustainable method to implement grazing and buffer projects in the region. The USC Grazing Initiative is supported by the development of the USC Ag Team that includes a Team Leader, a Coordinator, two Grazing Specialists, a GIS specialist, lead Data Collectors, and Technicians. This program's priority is to create "wall to wall" buffers by first focusing on fencing cattle from streams, as it is often the first step for farmers in our area who want to implement prescribed grazing. In addition, the USC Grazing Initiative developed a system to coordinate work with the NYS versions of federal programs such as CRP/CREP, EQIP/CBWI and others. We saw how the strength of coordinated approach is the ability to fill in gaps between other existing programs by leveraging funds from multiple sources, rather than competing with them. Finally, this project demonstrated how using a coordinated approach with a team of Ag experts maximizes implementation in the region due to the ability to identify priorities and needs on a larger scale, and having the network of communication to allocate resources in response.

The USC Ag Team members include:
Amanda Barber – Team Leader
Aaron Ristow – Ag Coordinator
Troy Bishopp – Grazing Specialist to the Eastern Region
John Wickham – Grazing Specialist to the Western Region
Chris Yearick – GIS specialist
Joann Burke – Lead Data Collector of the Eastern Region
Jody Appleby – Lead Data Collector of the Western Region
Technical Staff – In addition to the team above, most Districts in the USC have their own technical provider that can tap into the USC resources including capacity building through trainings and technical assistance from the Grazing Specialists, GIS Specialist and Data Tracking and Reporting.

2) Expand Grazing Initiative Buffer Program through additional grants

In 2011 and 2012 two buffer related proposals were submitted. The first was a 5-year, $2.2M request to the NYS Soil and Water Conservation Committee to fund a special project that would support a cattle exclusion/buffers/grazing program (Appendix G). This proposal identified the tremendous need and capacity in this watershed to implement grazing and buffer practices. USC Districts estimate that they have the capacity to install over 25 miles of cattle exclusion and buffer related fencing alone in the next 5 years (Table 4). The practices often come with additional BMPs such as alternate clean water sources, laneways, stream crossings, and converting land to pasture or improving acres of existing pasture. It was proposed that, where possible, these practices would be matched with federal programs such as the Chesapeake Bay Watershed Initiative (CBWI) and the Conservation Reserve Enhancement Program (CREP). The resulting "wall to wall" buffers created from this project would have continued the effort to reduce nutrient and sediment runoff to streams, help the NY State reach its TMDL WIP II goals and support a more sustainable farming industry.

Table 4. List of buffer related practices, the units to be installed, and the total cost.

Practice	Unit	Cost
Cattle Exclusion Fencing/ Buffers	25 miles	$350,000
Alternative Water Supply	100 farms	$400,000
Laneways	100 farms	$280,000
Stream Crossings	50	$200,000
Conversion to Pasture	200 acres	$120,000
Technical Support	24,800 hrs of staff time	843,200
	Total	**$2,193,200**

The second proposal was a 3-year, $200,000 request to NFWF's Stewardship Fund to continue to build upon the successes of the EBM grant. The proposal was titled "Developing Protocols for a Buffer Initiative in NY" (Appendix H). The primary output of the project was to utilize the AEM program for advancing buffer implementation on crop and pastureland to maximize potential environmental benefits. The projects were to combine two or more funding sources/programs to develop a working buffer project.

One of the lessons learned from the EBM project was that integrating several funding sources with slightly different approaches is challenging in our region. Therefore the USC Ag Team identified the need for a Chesapeake Bay Buffer Coordinator, directed by a NYS Conservation

Buffer Workgroup, to concentrate their time to take full advantage of all of these existing elements by bridging all three focus areas and simplifying the process at the state level to access federal and state programs and maximize the implementation efforts of local technicians on the ground. The outcome of the process would be to demonstrate that Districts could use the AEM program as an effective method to integrate and deliver federal, state, and local buffer programs by integrating them into one process. In addition to integrating programs at the state level, the Workgroup was to develop and lead trainings and outreach events for local technical staff on buffer planning and design as well as instructing technicians and landowners on how they can best leverage a variety of funding sources to maximize implementation.

As previously mentioned, neither proposal was funded but similar proposals will be submitted in the future.

Appendix A - Variable Source Hydrology Final Report

FINAL REPORT

Mapping Hydrologically Sensitive Areas

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Submitted to
The Upper Susquehanna Coalition

October 1, 2012

Executive Summary

In the northeastern US a relatively small portion of the landscape generates a disproportionately large percentage of its storm runoff. Protecting these runoff-prone areas, referred to as hydrologically sensitive areas (HSAs) from potentially polluting activities is an effective strategy for reducing nonpoint source (NPS) phosphorus pollution. Conceptually, we recognize that these are areas where soils are effectively prone to saturate such as areas of topographic convergence, the toe-slopes of hillsides, and soils underlain with a shallow layer of low permeability. For making land management decisions we need a way to reliably quantify the runoff risk associated across the Upper Susquehanna River Basin (USRB). We developed a method that accounted for both rainfall magnitude and antecedent wetness conditions to map runoff prone areas for any risk level. We applied this HSA-mapping methodology to nine sub-watersheds within the USRB where sufficient stream discharge and rainfall data were available. There were some inherent differences in the HSA risks among the nine basins, most of which we cannot yet explain. The exception is for watersheds with notable urbanized areas, which resulted in higher HSA-risks. To generalize our findings to the entire USRB, including un-gauged sub-watersheds, we used an average risk function based on the eight basins without substantial urban development. We have included land characteristics and risk functions for each watershed so that the method can be tailored to specific un-gauged watersheds if necessary, i.e., one can choose the risk function associated with one of our nine watersheds that appears to be the most similar to a specific un-gauged watershed. The base maps and final analyses are available in ArcGIS format.

Background and Justification

The overall objective of this project was to integrate water quality protection efforts throughout the watershed for three "implementation focus areas:" buffers, streams, and wetlands. One common characteristic of these implementation focus areas is that they are prone to be wet because of their location in the landscape. Strictly speaking, buffers are not consistently placed in saturation-prone locations. However, research has shown that their effectiveness in preventing NPS pollution associated with storm flow is enhanced if they are strategically placed in areas that naturally saturate (e.g., Agnew et al. 2006, Easton et al. 2008, Walter et al. 2009). The rationale for targeting water quality protection strategies to areas in a watershed most likely to saturate (or nearly saturate: Lyon et al. 2006) is that these are the areas, often called variable source areas (VSAs), that generate a disproportionately large fraction of the storm runoff (e.g., Beston 1964, Dunne and Black 1970, Dunne et al. 1975, Walter et al. 2000, 2001).

The term "hydrologically sensitive areas" (HSAs) was coined to refer to these parts of a watershed that are have the highest risk saturating and generating storm runoff (e.g., Walter and Walter 1999). These areas typically constitute a relatively small fraction of the overall watershed area (e.g., Frankenberger et al. 1999, Walter et al. 2000). Our role in the overall project was to develop a methodology for mapping HSAs so that the USC can use these HSAs locations to help select implementation sites suitable to construct wetlands, rehabilitate streams, install riparian buffers and implement prescribed grazing (e.g., wall to wall buffers) and cattle exclusion. Specifically, we developed a methodology for quantifying runoff risk (probability) for each point in the landscape. An HSA has three fundamental attributes: 1) risk level (e.g., return period), 2) fraction of watershed likely to generate storm runoff, and 3) the locations in a watershed where storm runoff is most likely to be generated. The following report is largely paraphrased from a research paper prepared by Cheng et al. (in preparation).

HSA Mapping Method

The method used here employ the widely used Soil Conservation Service (SCS, currently the Natural Resources Conservation Service - NRCS) Curve Number (CN) method, which has been adopted to predict areas generating storm runoff for watershed planners and land managers (e.g., Steenhuis et al. 1995, Gburek et al., 2002; Lyon et al. 2004, Walter et al., 2009). The SCS-CN equation was originally developed to predict storm runoff (SCS, 1972):

$$Q = \frac{{P_e}^2}{P_e + S} \tag{1}$$

Where Q is the runoff volume over the watershed (mm), S is the maximum available soil storage (mm), and P_e is the effective precipitation (mm); P_e = total precipitation (P) minus initial abstraction (I_a); I_a is the minimum amount of rainfall that is necessary to initiate runoff. Runoff depth, Q, is assumed to be distributed over the entire watershed.

We used a simple approach to estimating the amount of area producing runoff (A_p) based on the following equality (Gburek et al. 2002):

$$Q \times A_{ws} = P_e \times A_p \tag{2}$$

where A_{ws} is the total watershed area. The fraction of a watershed that is generating runoff (A_f), i.e., "saturated" areas, can be calculated as (Guberk et al., 2002; Walter et al., 2009):

$$A_f = \frac{Q}{P_e} \tag{3}$$

Substituting Eq.1 into Eq.3:

$$A_f = \frac{P_e}{P_e + S} \tag{4}$$

One implicit problem in the way the SCS-CN method is used is that the runoff excedence probability or return period is assumed to be the same as that of causative storm events. This is generally not the case (Shaw and Riha, 2011) and almost definitely not true for areas where the process of runoff production is governed by VSA hydrology (Walter et al., 2009). In addition to precipitation, antecedent soil moisture conditions also influence runoff generation, often in complex ways (Walter and Shaw 2009, Merz and Blöschl 2009, Macrae et al. 2010).

We used the method proposed by Shaw and Walter (2009) who accounted for antecedent wetness conditions by linking antecedent soil wetness, which influences S in Eq.1, to base flow immediately preceding the storm event. Specifically, we back-calculate S from observed pairs of Q and P_e for storms, noting the pre-rain base flow (Q_{base}) for each:

$$S = \frac{{P_e}^2}{Q} - P_e \tag{5}$$

Shaw and Walter (2009) showed that a power function fits the S-Q_{base} relationship for a watershed allowing the estimation of S from Q_{base}.

Shaw and Walter (2009) were then able to use a bivariate approach to the SCS-CN method and here we employ the same approach to estimate risks associated with the fraction of a watershed generating runoff (A_f):

$$\Pr\left(A_f = A_{f_i}\right) = \sum \Pr\left(P_e = P_{e_i}\right) \times \Pr\left(S = S_i\right) \tag{6}$$

where A_f is determined from Eq. 4, the probability distribution of S is based on the probability distribution of corresponding Q_{base}, which was developed based on the temporal histogram or "fraction of time" of Q_{base}, the rainfall probability was based on the most recent 40-years records.

To map A_f for any risk level (Eq. 6) we use the method proposed by Lyon et al. (2004), which has been adopted by some watershed modelers (e.g., Schneiderman et al. 2007, Easton et al. 2008, Walter et al. 2009, Buchanan et al. 2012). This method uses a version of the soil topographic index (*STI*) proposed for watersheds dominated by shallow restrictive layers, such as those with a fragipan or are shallow depth to bedrock (Walter et al. 2002)

$$STI = ln\left(\frac{a}{DK_{sat}\tan\beta}\right) \tag{7}$$

Where a is the upslope contributing area, D is the soil depth above the impervious layer, K_{sat} is the average soil permeability (or saturated hydraulic conductivity), and $\tan\beta$ is the local topographic slope. High STI-values indicate areas that have a high propensity of being wet with drier areas having low values of STI.

To map HSAs associated with a specific risk, we identify the fraction of the watershed with high *STI*-values that is equal to A_f (Eq. 4) for a specific probability (Eq. 6) (Figure 1).

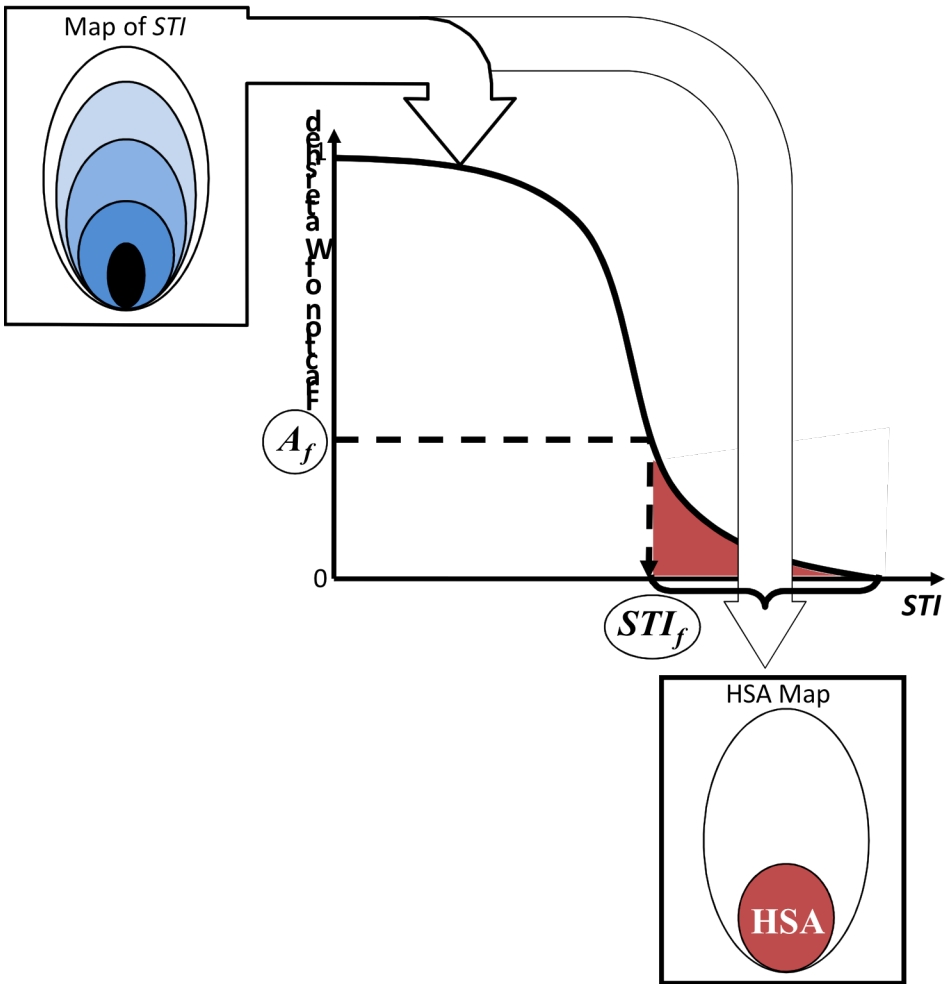

Figure 1. Schematic of the HSA mapping method. A map of STI-values (Eq. 7) is used to determine the relationship between STI and the fraction of the watershed with lower STI values. Every A_f (Eq. 6) has an associated STI_f value (dashed line) such that all parts of the watershed with higher STI-values (shaded area in graph) represent HSAs. The STI map can be used to map the HSAs.

Application to USRB

We chose nine stream-gauged sub-basins in the USRB (Figure 2, Table 1) based on three criteria: 1) Size: Considering the representativeness of the observed data from stream gages and rain gages, we mainly chose basins of relatively small size, less than 700 km2 (300 mi2); To investigate the effect of basin size on runoff generation, we included two larger basins (A and B, Fig. 1); 2) Location: We chose the sub-basins distributed across the Upper Susquehanna River Basin; 3) Data Availability: We selected the sub-basins with most available recorded data.

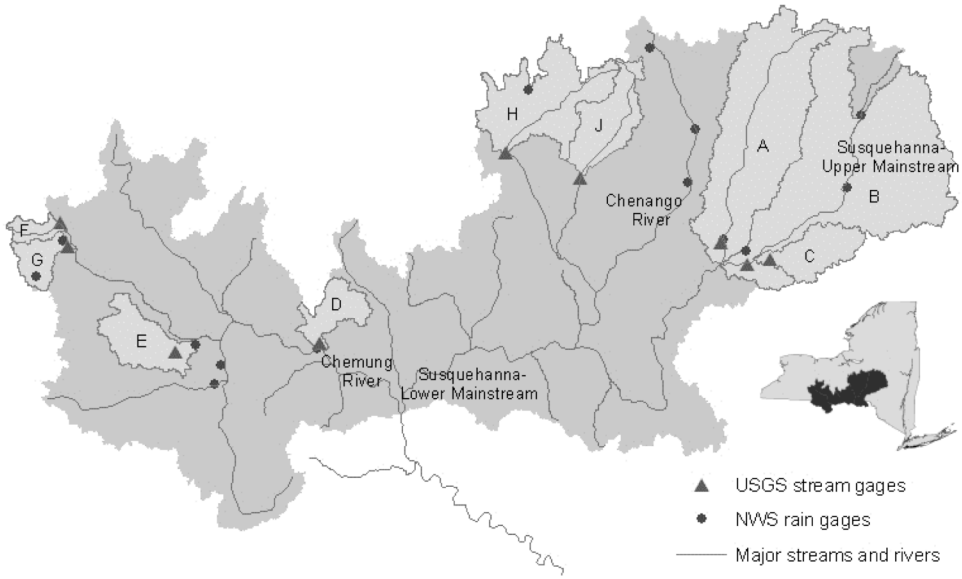

Figure 2. Nine studied sub-basins (lighter areas) and related US Geological Survey stream gauges (triangles) and National Weather Service rain gauges (circles).

Table 1. Characteristics of nine studied sub-basins and the entire basin

Sub-basin		***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***J***
Area (km²)		1350	2540	270	200	260	80	150	760	380
Average Slope (°)		6.5	7.6	8.1	6.5	7.3	6.9	8.1	7.2	7.4
Average Elevation (m)		453	503	541	398	509	548	562	464	484
Average Soil Depth (cm)		104	99	75	97	74	/	/	/	80
Average Annual Rainfall (mm)		1073	1079	1099	946	874	943	952	1069	1077
Average Temperature (°C)						0 - 15				
Land Use*(%)	Forest	48	59	61	54	51	74	70	52	62
	Agriculture	35	27	30	22	41	20	20	31	24
	Developed	3	5	4	16	4	1	5	5	3
	Open water/Wetlands	8	7	3	3	0	1	1	7	6
Number of events used to establish S-Q_{base}		19	16	16	36	18	16	11	18	16
CN for traditional SCS-CN method		71	72	70	75	72	71	71	74	73

*From National Land Cover Database (NLCD) 2006, zone 63, USGS

Daily weather data were taken from the National Oceanic and Atmospheric Administration (NOAA) weather stations (circles in Figure 2), which are available from the US National Climate Data Center. We used data records from 1998 to 2008 to back calculate S (Eq. 5). We selected precipitation events over 5 mm (0.2 inches) that were distinct in time with no rainfall for at least three days before and three days after and occuring during non-snowmelt periods (May-October). We used inverse distance weighted (IDW) interpolation of gauges within and surrounding the basin to estimate precipitation values for each sub-basin.

Daily stream-flow data collected at the US Geological Survey (USGS) gauges located at the outlet of each basin (triangles in Figure 2) from 1998 to 2008 were used to determine storm runoff. Base flow was extracted using the local minimum method, which is automated in the web-based hydrograph analysis tool (WHAT) (Lim et al., 2005). The number of pairs of weather data and stream-flow data we used to establish the relationship between S and Q_{base} for the nine sub-basins ranges from 11 (basin G) to 36 (basin D).

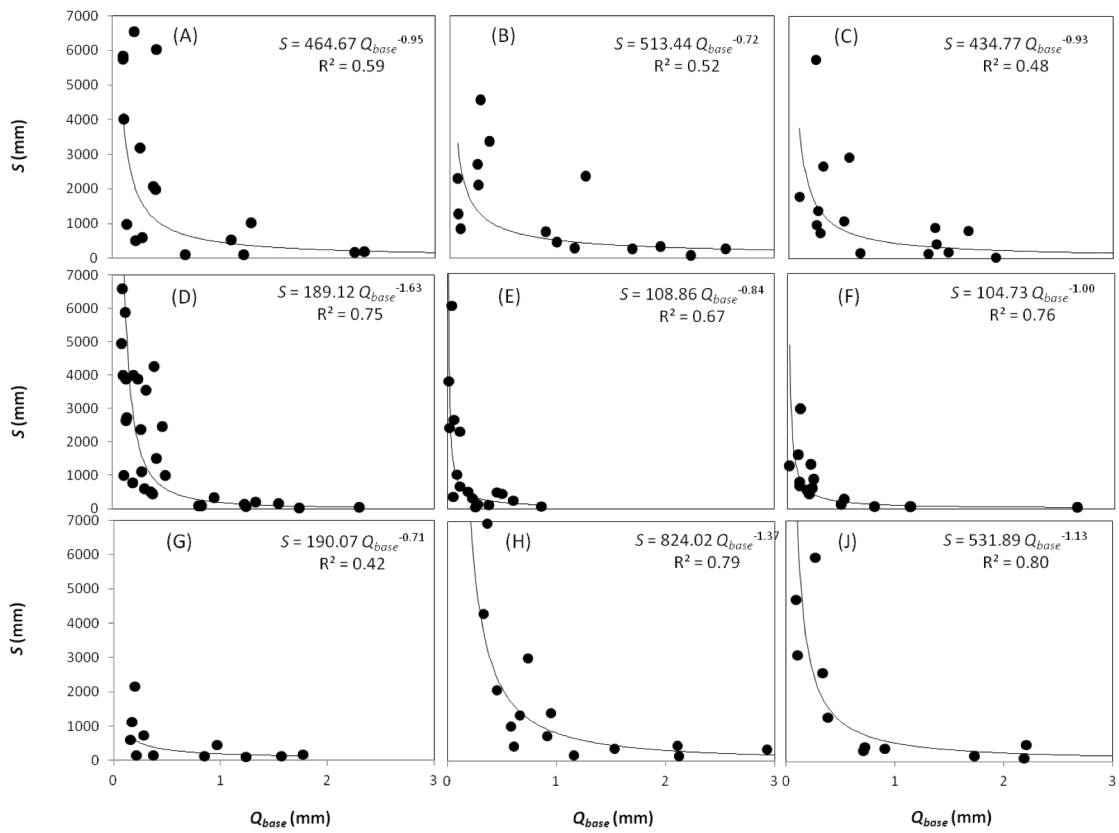

Figure 2. S versus Q_{base} for nine studied sub-basins of the Upper Susquehanna River Basin. The letters correspond to the sub-basins in Table 1. Circles represent pairs of back-calculated S-values from observed P-Q data and base flow immediately preceding the rain event, Q_{base}; lines are best-fit power-functions; power functions and associated R^2 are shown in each graph.

The relationships between S and Q_{base} for each sub-basin were fit by power functions (Figure 3). Basin J had the highest correlation (R^2 = 0.80), while basin G, the one with the least available data, had the lowest correlation (R^2 = 0.42).

Based on these S-Q_{base} relationships, we S-values from Q_{base} for 28 independent events representing a wide range of Q_{base} frequencies or probabilities. Using 11 P-values and the 28 S-values, we obtained 308 A_f values for each basin. We were then able to estimate bivariate risks associated with A_f using Eq.6 (solid lines in Figure 3). We also calculated A_f assuming we could ignore antecedent wetness state, i.e., the risk (shown as return period in Figure 3) was equal to the return period of the rainfall event (dashed lines in Figure 3). As was perhaps anticipated, there are much more marked differences among A_f risks among the basins when we considered antecedent wetness conditions (Figure 3).

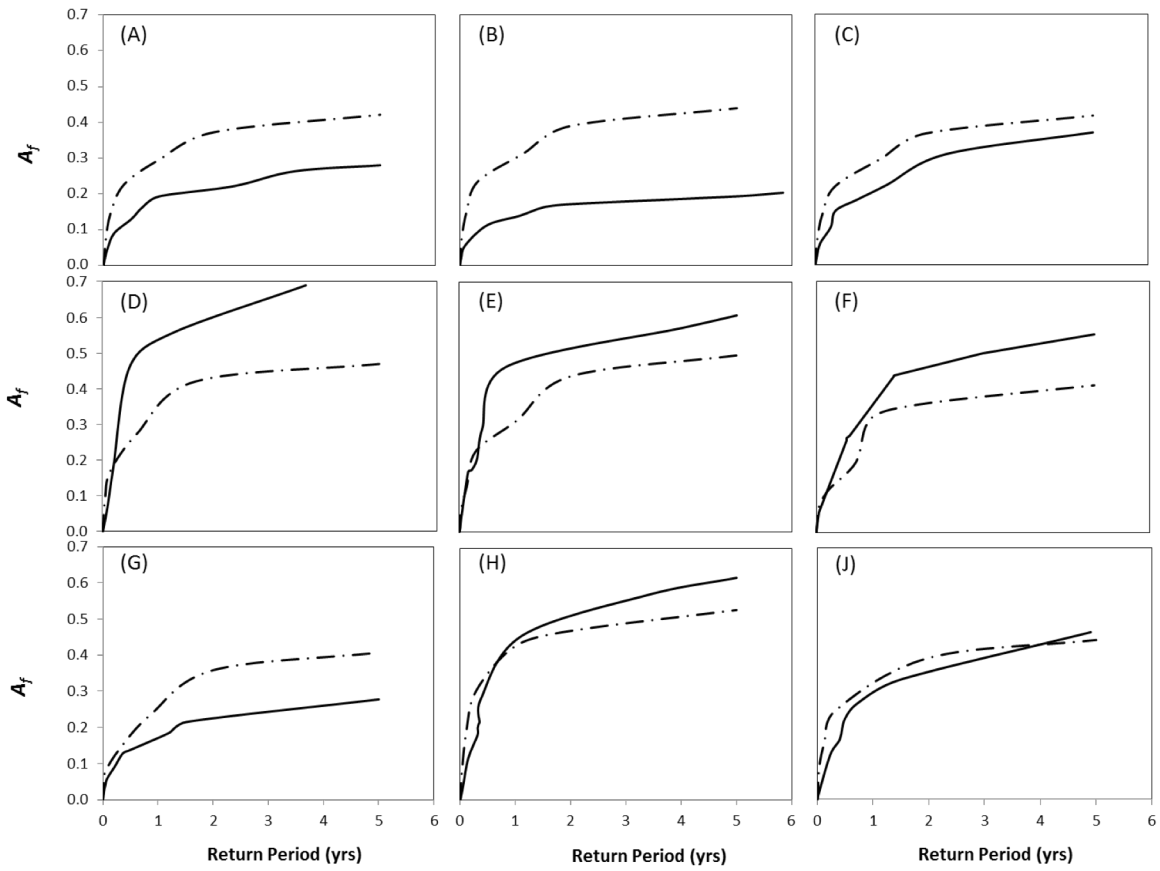

Figure 3. Comparison of risks associated with runoff producing areas (A_f) between bivariate SCS-CN (solid line) and traditional SCS-CN (dashed line), which ignores antecedent wetness conditions. Letters correspond to sub-watersheds (Figure 2, Table 1).

Unfortunately there are no sufficiently long records of soil saturation state or storm runoff from the landscape to use for corroborating our results. As a "back-of-the-envelop" test we identified four storm events for sub-watersheds B and D that generated storm runoff with return periods between 2- and 5-years. We considered the ratio of observed storm runoff to observed precipitation to be a reasonable approximation of A_f (Eq. 3). For sub-watershed B the average A_f corresponding to the 2-5 year return periods was about 20% (Figure 3B) and the A_f based on the four observed storm events was 24% (range 13-30%). Similarly, for sub-watershed D we found average 2-5 year A_f = 47% (Figure 3D) compared to an "observed" A_f of 48% (range 38-59%). If we do not consider the antecedent wetness conditions we predict an A_f of about 40% for both watersheds. Although this is only a cursory test, the values we

calculated using our bivariate approach were within 5% of the "observations," which is generally considered very good in hydrology (personal experience).

As a demonstration of HSA mapping we mapped the 1-year A_f locations for sub-watershed J (Figure 4); i.e., all areas that generate storm runoff on average 1 time per year or more frequently are considered HSAs. Data for creating HSA for all sub-watersheds is freely available upon request.

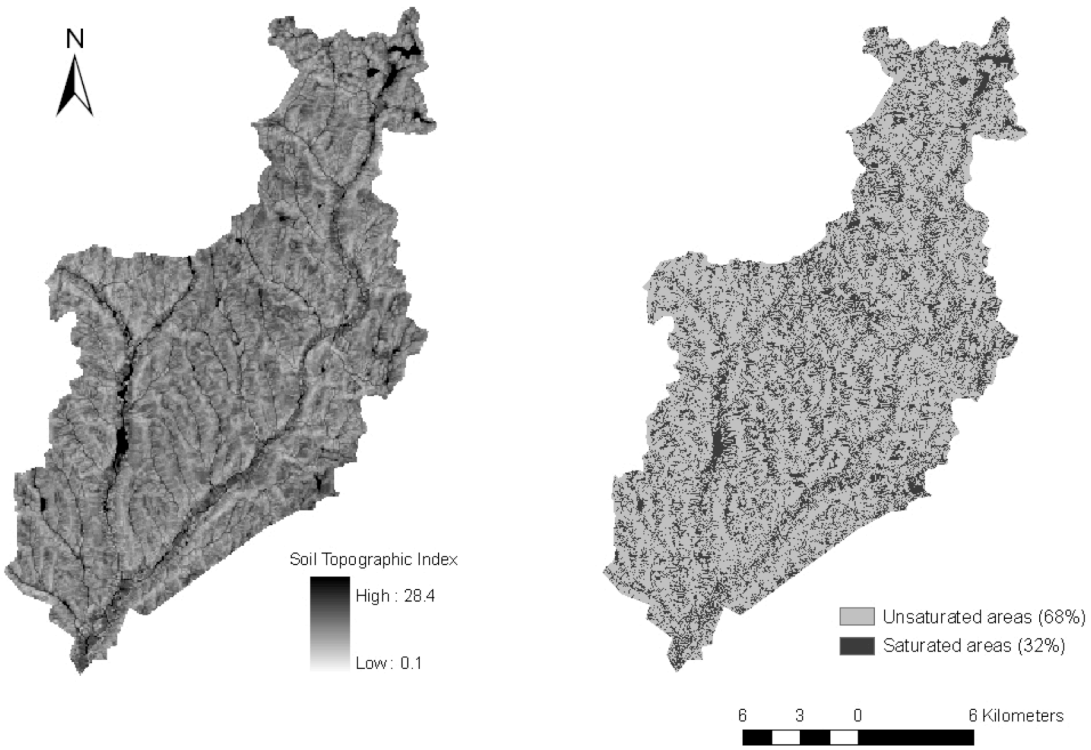

Figure 4. *STI* map (left) and map of HSAs associated with a storm runoff frequency of once every two years or more often (return period = 1-year) (right) for sub-basin J.

Unfortunately, we have not yet found a way to generalize the relationships shown in Figure 3 to un-gauged watersheds. We think that the watershed characteristics (Table 1) are at least partially explanatory. For example, sub-watershed D has uniquely high A_f values that we speculate are associated with its uniquely high fraction of developed or urbanized area (Table 1). It is possible the sub-watersheds E and F, which also have relatively high A_f values may be related to high fraction of agricultural land (E) and small size (F) (Table 1), but we can only speculate at this point. Thus, when using our mapping method for sub-watersheds in the USRB we recommend matching it to the closest of the nine used in this project and using the associated relationship shown in Figure 3. As rough approximation for the USRB as a whole, we used an average of eight sub-basins (excluding the relatively highly urbanized D sub-basin) (Figure 5).

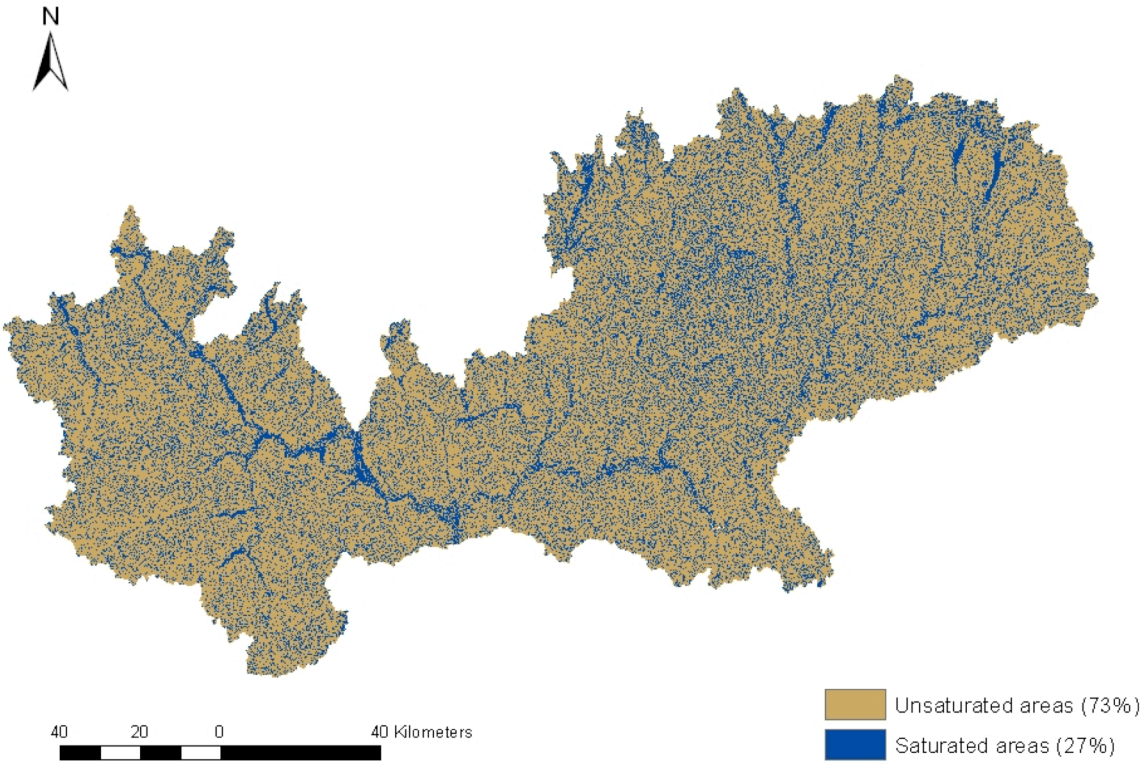

Figure 5. A composite HSA map for the USRB for the 1-year return period based on the average of sub-watershed A, B, C, E, F, G, H, and J. (note, this map uses a slightly different version of the STI, discussed in the next section.)

Discussion and Future Directions

Based on our previous and on-going research, we are confident that the methods described and used in this project are well-suited to the hilly, upland parts of the region. We are less confident about how these methods work in the valley bottoms. Unlike the hillsides, where the soils are generally shallow and underlain by fragipans and/or bedrock, the soils in the valley bottoms can be very deep. However, these deep soils generally have a permanent, albeit fluctuating, water table. The depth to this water table is the effective depth we would want to use in calculating our STI (Eq. 7). Unfortunately, we have not yet developed a sufficiently credible way to estimate this, although it is an area of active research. When we generated Figure 5 we removed D and K_{sat} from Eq. 7; this form is generally referred to simply as a topographic index (TI) because the soils information is removed. This form will miss some HSAs in the upland areas but appears to correctly predict that the valley bottoms will be hydrologically sensitive (Figure 5), at least for some parts of the year. If the STI was used, the valley bottoms would not be predicted to be areas of storm runoff generation (not shown here).

Another potential challenge for scaling-up our findings to large areas is that the available soils data are characterized on a county basis. Thus, the same soil unit's properties, e.g., D and K_{sat}, may change dramatically from one side of a county boarder to another. This means that the STI will be very different on different sides of a county boarder. We are currently testing different forms of TI, STI and similar indices to investigate alternatives that can address these issues.

As mentioned earlier, we are also working on ways to generalize our findings so that they can be applied to un-gauged watersheds. The sub-watersheds used in this study suggest that land cover may play a role, which previous VSA/HSA research has not identified. For now, we suggest using the nine sub-watersheds as archetypes or models for un-gauged watersheds, i.e., choose A_f from the watershed or watersheds that most resembles the un-gauged watershed of interest.

All data, maps, and analyses generated in this project are available as project deliverables.

Summary and Lessons Learned

- HSAs can be quantified and mapped for watersheds with stream gauges
- Independent data appear to corroborate our HSA estimates, although there is very little such data
- HSAs differ, sometimes substantially, throughout the USRB; land cover/use may contribute to this variability
- Additional work is needed to determine how to map HSAs in valley bottoms with deep soils/alluvium.
- Soil data that differ dramatically in their properties at county boundaries pose challenges for mapping HSAs.
- There are a variety of challenges for mapping HSAs in un-gauged watersheds, although we propose using the nine sub-watersheds used here as templates; i.e., use the results from this study for the watershed(s) with characteristics that most closely match the un-gauged watershed of interest
- We propose using average HSA (A_f) risks-fractional areas when scaling to very large watersheds like the entire USRB.

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