Baltimore Ecosystem Study

"Uncultivated"
By Lynn Cazabon

Annual Report 2012

Preface to the Annual Report

On the following pages is the Annual Report of the Baltimore Ecosystem Study (BES) for the period 2011-2012. The Baltimore Ecosystem Study, a Long-Term Ecological Research (LTER) project, was initiated in 1997. The BES is one of 26 LTER projects, representing diverse ecosystems and research emphases. It is funded by the National Science Foundation to learn how an urban area works as an ecological system. Over the last fourteen years we have learned new, and sometimes surprising, things about Baltimore's urban ecosystem. This report summarizes the most recent scientific and educational contributions BES has made.

As one of only two Long-Term Ecological Research sites focused on an urban environment, we want to know the ecological interactions in the whole range of habitats—from the center city of Baltimore, to the surrounding rural areas. We are conducting research on the soil, the plants and animals on land and in the streams, the water quality, and condition of the air in and around Baltimore. For that information to make sense, we are also studying how families, associations, organizations and political bodies make decisions that affect ecological processes. In other words, we are treating the whole collection of city, suburban and rural areas as a complex urban ecological system that includes people and their activities.

This is a really unusual approach to ecology because it combines with social sciences, physical sciences, and education to understand a big metropolitan area as an ecological system. Saying that an urban area is a system means that we are concerned with the interactions between wild and domestic organisms, people and their organizations, the natural and built environment, and how they all affect one another. It is these relationships that determine the quality of the environment we experience.

The program brings together researchers from many disciplines and organizations to collect new data and synthesize existing information on both the ecological and engineered systems of Baltimore. Our interest is not only with the present environment, but with the historical changes that have led to the conditions that exist today, and with the environmental trends into the future. The ecological knowledge BES creates helps support educational and community-based activities. Indeed, the interactions between our researchers and the Baltimore community are important components of our project. We hope that the information produced by our work, which integrates many disciplines and the efforts of many research and educational institutions in Baltimore and beyond, is of interest and use to you.

You may contact the researchers, educators, and professional members of the Baltimore Ecosystem Study through the Project Facilitator, Holly Beyar (BeyarH@caryinstitute.org), and locate updated information and additional information on the project through its website (http://www.beslter.org).

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Acknowledgement of Support

The Baltimore Ecosystem Study project is supported by the National Science Foundation Long-Term Ecological Research program, through grant numbers DEB 0423476 and 1027188. The USDA Forest Service Northern Research Station contributes research staff time, equipment, funds and in kind services to BES. In addition we thank the University of Maryland, Baltimore County for their contribution to office, laboratory and field space at the Center for Urban Environmental Research and Education. The US Geological Survey, the City of Baltimore Department of Recreation and Parks, the Baltimore City Department of Public Works, the Baltimore County Department of Parks, the Baltimore County Department of Environmental Protection and Sustainability, the Maryland Department of Natural Resources, and the McDonogh School all kindly provide information, access or management of land and equipment used by the Baltimore Ecosystem Study for ecological, hydrological, and meteorological field studies. Additional support and assistance has been provided by many agencies, communities and individuals who are listed in the report.

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"Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

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Annual Report 2012

Covering August 2011—August 2012

www.beslter.org

Report Guide and Format

Phase III – Adaptive Processes in the Baltimore Socio-Ecological System: From the Sanitary to the Sustainable City

Research Questions and Goals

The Baltimore Ecosystem Study (BES) Phase III builds on the foundation of the first two phases of the project, while introducing new theoretical and practical motivations and, consequently, additional integrative strategies. The growing focus of researchers, citizens, and decision makers on the sustainability of city-suburban-exurban (CSE) systems provides a new framework for extending and refining the long-term socio-ecological research of BES.

The first two phases of BES were guided by relatively straightforward questions that focused on 1) the spatial and institutional (sensu Ostrom) **structure** of metropolitan Baltimore, 2) the social and biogeophysical **processes** within various locations in the metropolis and their connections between different patches and between the social and biophysical realms, and 3) the flow of ecological **information** and its role in environmental understanding and quality of life. Such fundamental information will continue to be collected by BES research. However, the emergence of the sustainability paradigm and the existence and implementation of sustainability plans in the Baltimore region suggest a new overarching question for BES III:

> **How do biogeophysical and social adaptive processes influence and respond to policies aimed at enhancing sustainability in the Baltimore region?**

New Theoretical Frameworks

To add value to the exploration of the transition from the sanitary to the sustainable city (Grove 2009), BES examines three related theoretical realms. Within the context of evolving sustainability policy, we have adopted these major areas of adaptive processes for empirical and modeling focus:

- Locational choice and land change,
- Connectivity and dynamics of the urban river continuum and watersheds, and
- Biotic metacommunity dynamics.

These areas exploit existing theories that have not been used in previous phases of BES, while connecting with our on-going research.

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Activities

Activities are presented for each of the three theoretical areas –Locational Choice, Urban Stream Dis/Continuum, and Urban Metacommunity – and for education as a distinct category. In some cases, integrative connections across areas are mentioned.

Activities: Locational Choice

1. ***Environmental Justice: A Long Term Perspective***.
This study examines the density of polluting industry by neighborhoods in Baltimore over the long term, from 1950 to 2010, to determine if high pollution burdens correspond spatially with expected demographic and housing variables predicted in the environmental justice literature. For 1960-1980 we use data on heavy industry from Dun and Bradstreet directories and for 1990-2010 the US EPA's Toxics Release Inventory to calculate a Hazards Density Index. Drawing on the decennial censuses for 1960-2010, we populate census tracts from corresponding years with data on race, ethnicity, educational attainment, income, and housing tenure.

2. ***Environmental Justice***.
Supported by a grant from the Ohio University Baker Fund as well as NSF, BES Co-PIs Buckley and Boone conducted interviews with state and municipal government personnel to learn how asphalt removal projects in Baltimore are selected and funded.

3. ***Urban Composting***.
Ohio University graduate student Kylie Johnson completed her thesis in June 2012. She compared composting practices in Edinburgh (Scotland), Washington, DC, and Baltimore.

4. ***Change in forest patch structure in the Gwynns Falls watershed***.
Research was conducted on forest cover change by post-doc Weiqi Zhou. The spatial and temporal patterns of forest cover were analyzed from 1914 to 2004 in the Gwynns Falls watershed in Baltimore, Maryland based on a database of forest patches from six times: 1914, 1938, 1957, 1971, 1999, and 2004 that were derived from historic maps and aerial photographs.

5. ***Modeling Air Temperature Differences Across the Baltimore Region***.
The goals are to predict the effect of differences in land cover on air temperature at people height, to predict the effects of differences in tree cover on air temperature, and to evaluate park influences on air temperature. Participants include BES Co-PIs Gordon Heisler, David Nowak, Ian Yesilonis, John Hom, as well as researcher assistants Alexis Ellis, Emma Noonan, and grad student Hang Ryeol Na.

6. ***Urban Tree Cover Change in the United States***.
Paired aerial photographs were interpreted to assess recent changes in tree, impervious and other cover types in 20 U.S. cities as well as urban land within the conterminous United States.

7. ***Natural Regeneration in Cities***.
Field data from randomly located plots in 12 cities in the United States and Canada were used to estimate the proportion of the existing tree population that was planted or occurred via natural regeneration. In addition, two cities (Baltimore and Syracuse) were recently re-sampled to estimate the proportion of newly established trees that were planted.

8. ***Spatial Modeling of Residential Subdivision Development***.
The goal of this project is to develop parcel-level spatial econometric models to explain the timing, quantity and pattern of residential land development and to examine how changes in market factors and land use policies influence residential land use patterns. We reconstructed the residential subdivision history for Baltimore and Harford counties using historical subdivision plat image files from the Maryland State Archives (www.plats.net) and county tax assessors GIS databases. We dated the year of platting for residential subdivisions since 1960. The subdivisions were then reclassified as either a major or minor subdivisions. In addition, for subdivisions from 1980 onward, we reconstructed the entire internal history that records the timing and location of different development phases of the subdivision. We have also collected the name and address for the owner and developer for each subdivision platted during 1980-2008. Other data that we have collected and are in the process of linking to the historical subdivision data include information on the timing of approvals by the county of subdivision plans; the timing and location of agricultural preservation; zoning; distances to nearby towns and large cities; surrounding land uses and other amenities; soil quality and slope data. Similar data for Carroll County were assembled in 2010-2011. We used this dataset to construct a subset of data on all undeveloped and developed parcels in the county from 1995-2007. During this time period 410 of 3,852 parcels gained conditional subdivision approval. We created a parcel-specific dynamic measure of regulatory uncertainty that reflects the expected approval times for each developable parcel based on the observed variation in these approvals. A joint Probit-Poisson model of subdivision development timing and intensity was estimated using this parcel-specific measure of regulatory cost. The richness of the data enables us to identify the effect of implicit regulatory costs on development decisions while controlling for other parcel-level variables, including soil type, slope and other variables that influence development costs and returns.
BES funds have supported work that has enhanced our ability to obtain non-core LTER grant funds. These additional funds have supported additional data collection that complements the BES work. These additional NSF funds are from the following grant: Collaborative Research, WSC-Category 2: Regional Climate Variability and Patterns of Urban Development-Impacts on the Urban Water Cycle and Nutrient Export. PI: Claire Welty. Dates: January 2011–December 2015.

9. ***Agent-based Model of Exurban Land Markets***.

The goal of this project is to develop a two-dimensional spatial agent-based model of exurban land development that does not impose the standard long run spatial equilibrium assumption of the traditional urban economic model. Relaxing this assumption is necessary in order to better understand and model the short run spatial dynamics and heterogeneity that characterize urbanization processes and patterns. We develop an agent-based model of exurban land markets in which market interactions between households and landowners are explicitly accounted for in a way that does not impose a long run spatial equilibrium. This approach allows us to study the transition dynamics of land markets and the conditions under which leapfrog development emerges in the short run. A key innovation of the model is in the formulation of bidding for location by households that are heterogeneous in income. An auction model is used to derive a household's optimal bid for land that accounts for preferences, income and basic market conditions, including the number of competing bidders and relative land supply. A household identifies its optimal bid for a given location by choosing the bid that maximizes the expected surplus. Any surplus that is realized with a winning bid generates additional utility. Households submit optimal bids to landowners who make optimal timing decisions regarding the conversion of their agricultural land to a residential use. In each period, new households enter the region and compete for residential location along with a fixed proportion of existing residents. Land rents increase over time due to population growth and increased competition for location. We have applied this model to understanding leapfrog development patterns that are so common and persistent in exurban regions of the U.S. We implement the model of household location and landowner development on a two-dimensional landscape grid using spatial simulation methods. We have begun to apply the model to a real world landscape using GIS data from the Baltimore metropolitan region to measure road network distances and the physical conversion costs of parcels.
BES funds have supported the creation of data that have been used to specify the agent-based model and apply it to a real world landscape. The development of the computer code needed to implement the agent-based model has been supported by two non-core LTER grants: (1) NSF Geography and Spatial Sciences Collaborative Research: Spatial Dynamic Modeling of Exurban Land Markets and Land Use Patterns. PIs: Elena Irwin and Yong Chen. Dates: September 2011–August 2013. (2) John S. McDonnell Foundation Study of Complex Systems Grant: Multi-scale Dynamics and Emergent Patterns in Urban Spatial Systems. PI: Elena Irwin. Dates: October 2008–September 2013.

10. ***Environmental Determinants of Crime.***

Conducted extensive statistical research on the relationship between tree cover and crime and between property landscape management and crime, using geocoded crime data and high resolution land cover. We ran linear regressions, as well as spatially adjusted regressions and geographically weighted regressions.

11. ***Social Network Analysis***.

Grad student Michele Romolini worked on social network analysis of environmental stewardship groups in Baltimore. An inventory was conducted of 1200+ organizations in Seattle and Baltimore involved in environmental stewardship activities. The mixed method approach included ethnographic and historical research; citywide social surveys of organizations; and statistical and social network analysis.

12. ***Mapping Transition Zones***.
Grad student Holli Howard conducted extensive GIS analysis of the interface/ transition zone between urban and exurban portions of greater Baltimore. This involved the development of a method for using cluster analysis to map "transition zones" between urban and rural areas in the greater Baltimore region.

13. ***Property Values and Environmental Disamenities***.
Conducted preliminary analysis on the impacts of divided highways on property values in Baltimore.

14. ***Yard Management.***
Developed a new method for characterizing level of yard management using factor analysis of responses from yard management survey

Activities: Urban Stream Dis/ Continuum

1. ***Legacy Effects of Structural Catchment Changes****.*
Efforts of BES Co-PI Dan Bain in long-term ecological research over the last year have largely been accomplished via leveraged funding from the LTER Network office. Reporting from an earlier synthesis working group was completed (http://intranet2.lternet.edu/documents/long-term-hydrologic-change-disturbance-legacies-material-fluxes) in an article in *BioScience* using BES and other LTER data to define fundamental concepts in legacy effects (e.g., a legacy time criterion and differentiation between structural and signal legacy effects). In addition, in collaboration with Gajan Sivandran (Ohio State), Mark Green (Plymouth State), and Tony Parolari (MIT), we are using long-term research site records to build calibrated hydrologic models, implementing legacy effect causing scenarios in the model, and quantifying the change by difference. This work will continue and expand through the working group conducted at the 2012 All Scientists Meeting.

2. ***Pond Branch: Geomorphology, Hydrology, and Ecosystem Dynamics Influence on Nitrogen Cycling.***
Grad student Jon Duncan has continued work on examining the influence of geomorphology, hydrology, and ecosystem dynamics on nitrogen cycling in Pond Branch. This has evolved into two separate questions:
   1) what is the mechanistic basis to summer peaks in nitrate?
   2) how much denitrification occurs in riparian soils?
These stem directly from theories of nitrogen saturation and the ability for ecosystems to process large amounts of reactive nitrogen. Contrary to behavior predicted by the nitrogen saturation hypothesis, the Pond Branch watershed in the Maryland piedmont exhibits peak nitrogen export during the growing season. The majority of nitrate is exported at baseflow, yet groundwater concentrations are depleted relative to the stream. Furthermore, detailed soil core studies have shown

that the majority of nitrogen cycling occurs within surface soils, a zone not directly connected to the stream during summer baseflow conditions. We have examined the role of microtopography and soil moisture variability as hydrologic controls on watershed nitrogen export by combining high frequency spatially distributed measurements and models. Upland, hillslope hollow, and riparian hummock and hollow locations were identified as fundamental landscape units. We instrumented each landscape unit with soil oxygen, soil moisture, and groundwater wells and collected soil cores during each season (Figure 2). Limited duration high temporal resolution (15 minute) measurements of stream nitrate concentrations at the outlet were used to assess how landscape heterogeneity of soil moisture and oxygen relate to summer nitrate export. Analysis of soil cores at varying oxygen concentrations using a new gas flow method show that riparian locations have higher rates of N_2 flux at 5 and 10% O_2 than 0%, suggesting that denitrification is nitrate limited and that there is tight coupling between nitrification and denitrification. Stream nitrate concentrations reveal that the seasonal summer increase (0.04 mg/L to 0.18 mg/L) occurs during baseflow over the span of several days. Complimentary data of groundwater tables, soil moisture, and soil oxygen show marked diurnal variability and demonstrate a strong relationship to the rapid increase of nitrate concentrations.

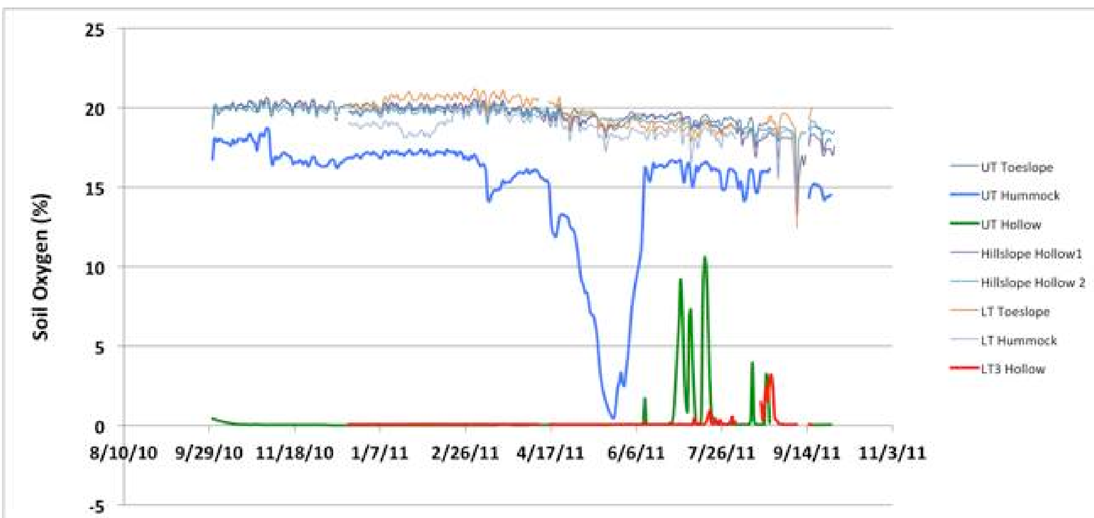


Figure 2: Soil O_2 levels in riparian Upper Transect, Lower Transect, and hillslope locations show significant transitional behavior of riparian locations as N hot spots

Closing the nitrogen budget is a major scientific challenge at multiple scales. One of the largest sources of uncertainty is the importance of denitrification. Determining in situ rates of denitrification in elements of landscape that remove a disproportionately high amount of N from certain areas of catchment (hot spots) in response to seasonal and event driven conditions (hot moments) is critical to closing watershed nitrogen budgets. We develop an approach to scale denitrification flux from seasonal soil cores collected in different landscape positions to the entire watershed using a combination of laboratory core experiments, terrain analysis and in situ soil oxygen and soil moisture content sensors. In the Pond Branch watershed, nitrogen deposition values are relatively high (10kg/ha/yr) with very little export in streams (0.5 kg/ha/yr). Soil oxygen sensors were placed in different landscape positions throughout the watershed and reveal that riparian zones are the primary zones of anoxia even during tropical storm Lee that delivered more than 100mm of rainfall across the watershed. Of particular importance to the nitrogen cycle are the oxygen dynamics in riparian hollows. These zones remain anoxic for most of the year except for short periods of time during the driest summer months. By combining in situ oxygen data and experimental determination of N_2 flux under different oxygen concentrations, we built a model to predict daily N_2/ denitrification fluxes for different portions of the landscape. By combining the experimental and in situ sensor data with terrain analysis, we were then able to develop estimates of daily N_2 flux for the watershed.

3. ***Ecohydrologic Modeling of Stormwater and Associated Ecosystem Processes.***

Grad student Brian Miles, University of North Carolina, Chapel Hill is working on research that emphasizes stormwater management as a key element of urban sustainability. We are developing an approach for ecohydrologic modeling of stormwater, and associated ecosystem processes of water, carbon and nutrient cycling in highly impervious catchments that is reliant on high resolution observations of the natural and built environment, and high performance computing (HPC). As a complement to the research in Pond Branch, this adapts the RHESSys modeling approach to Dead Run, using BES high resolution LIDAR, EMERGE imagery object classifications (U. Vermont, Figure 3), direct observations of small scale connectivity at the household level (downspouts, run-on infiltration), and the set of discharge, nitrogen concentration, and lawn fertilizer measurements carried out through the BES and associated projects. Results will advance our understanding of the effectiveness of small scale neighborhood design practices, and household stormwater management on stormwater volumes and nutrient pollution in urban catchments, and will develop HPC tools that can be used by managers to assess stormwater processes from different development and BMP management practices. Specific questions posed include:

- How does residential impervious surface connectivity influence nitrogen export from urbanized watersheds?
- Are changes in nitrogen export due to residential impervious surface disconnection sensitive to: (a) where in the watershed disconnection takes place (riparian v. headwater); or (b) composition of redirected runoff receiving area (rain garden v. lawn)?
- What ecosystem disservices may result from such redirection of residential stormwater, and where in urban watersheds are these side effects likely to occur?

Software tools developed include an automated workflow environment to set up, parameterize, calibrate and visualize RHESSys models for Dead Run 5, and for a similar catchment in Ellerbe Creek in Durham, NC. The workflow is written in integrated Rule Oriented Data (iRODS) system to integrate data access, management, processing, and provenance. Initial results have developed working models of the two catchments, and have automated much of the RHESSys construction, integration and operations.

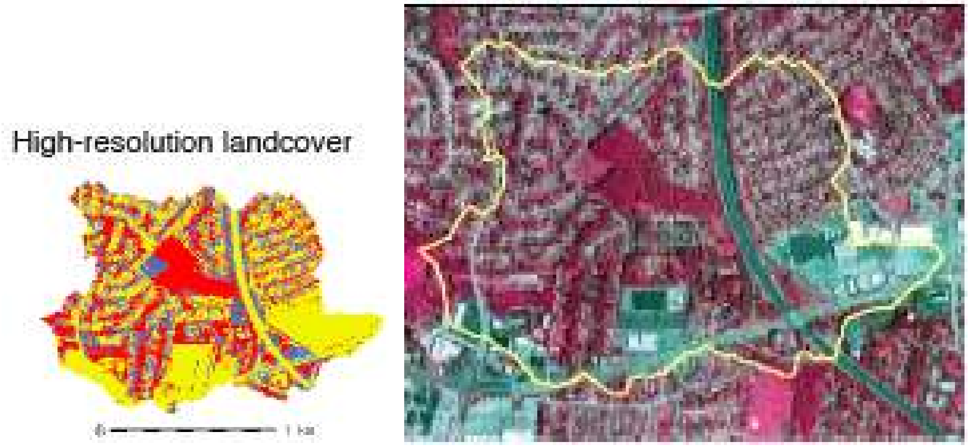


Figure 3: EMERGE airborne multispectral imagery of Dead Run 5 (right) and HERCULES classification.

4. ***Streamflow Monitoring—Urban Hydrologic Networks and Reference Watersheds***

This work is funded by core BES funding, the Baltimore County Department of Environmental Protection and Sustainability, and the U.S. Geological Survey. Since 1998, USGS has operated 5-6 streamgages using full or partial NSF funding that provides part of the base infrastructure for physical investigations by the Baltimore Ecosystem Study. The station locations were selected partly to provide watershed coverage on the main stem of Gwynns Falls, and also to provide data in selected small watershed reference land-use conditions. In addition to stations operated as part of the base infrastructure of BES, USGS operates five additional full-service streamgages in the Gwynns Falls watershed, and approximately 30 other stations in the Baltimore region through funding from USGS and local cooperators. All data are managed within the USGS database. Data are analyzed, and streamflow records are computed on a continuous basis. Records are then checked, reviewed, and approved in the USGS database. All discharge data are published each year in the USGS Annual Water-Data Report http://wdr.water.usgs.gov/.

USGS staff completed several hydraulic computations in both open channels and culverts to determine peak discharges at selected BES stream gages for the flood event produced by Tropical Storm Lee (September 7, 2011).

In addition to ongoing network activities, the USGS collaborated with USEPA, Office of Research and Development during 2012 to complete a USGS interpretive report that compares pre and post restoration geomorphic conditions in a small urban watershed in Baltimore County, MD (Minebank Run).

5. ***The Urban Stream Syndrome***.

One of the most obvious effects of urbanization is the development of “urban stream syndrome” which is characterized by lower riparian water tables, drier riparian soils and loss of the riparian nitrogen removal function. In BES, long-term monitoring of riparian water tables and groundwater chemistry began in 2000 along four first or second order steams in and around the Gwynns Falls watershed in Baltimore City and County, MD. One site (Oregon) is in the completely forested Pond Branch catchment that serves as a "reference" study area for the Baltimore LTER (BES).

Two sites (Glyndon, Gwynbrook) are in suburban areas of the watershed; one just upstream from the Glyndon BES long-term stream monitoring site in the headwaters of the Gwynns Falls, and one along a tributary that enters the Gwynns Falls just above the Gwynnbrook BES long-term stream monitoring site farther downstream. The final, urban site (Cahill) is along a tributary to the Gwynns Falls in Leakin Park in the urban core of the watershed. These datasets are now serving as a platform for more detailed modeling and process research as part of an NSF funded Water Sustainability and Climate grant led by BES Co-PI Dr. Claire Welty at UMBC-CUERE. (Figure 4)

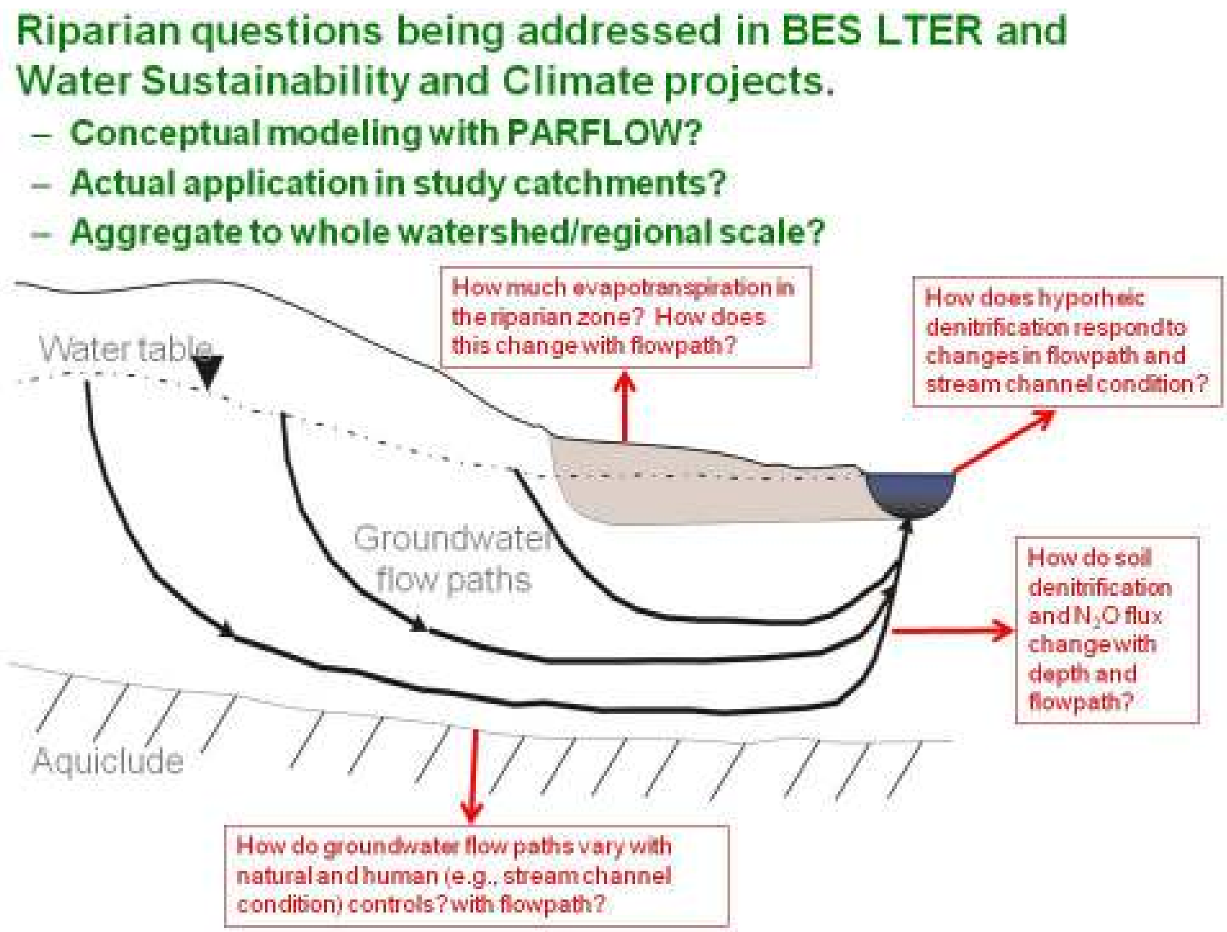


Figure 4 Riparian biogeochemistry questions being addressed in new BES-related Water Sustainability and Climate project.

6. ***Environmental Planning Instruments for Watershed Protection.***
Grad student Danielle Spurlock is involved in a collaborative effort between BES and the NC Triangle ULTRA to analyze and compare the strength, comprehensiveness and efficacy of environmental planning instruments for watershed protection. The project is carrying out a content analysis of a hierarchy of planning and

implementation documents including comprehensive plans, local ordinances, and permit applications (including requested variances) in the Baltimore metropolitan area and in the NC Triangle region. Both areas are highly urbanized and are under current TMDL to reduce nutrient export to proximal downstream water bodies (Chesapeake Bay, and the Jordan Lake and Falls Lake reservoirs).

7. ***The Urban Watershed Continuum.***

Co-PIs Sujay Kaushal and Ken Belt proposed an urban watershed continuum evolving spatial and temporal dimensions with active management or degradation, and provided examples from the BES LTER site. This model recognizes that the nature of hydrologic connectivity influences downstream fluxes and transformations of carbon, contaminants, energy, and nutrients across four space and time dimensions.

8. ***Influence of Organic Carbon Sources on Denitrification.***

Organic carbon is important in regulating ecosystem function and its source and abundance may be altered by urbanization. We investigated shifts in organic carbon quantity and quality associated with urbanization and ecosystem restoration, and its potential effects on denitrification at the riparian-stream interface, by field measurements of streamwater chemistry, organic carbon characterization and lab-based denitrification experiments at two forested, two restored, and two unrestored urban streams at the BES LTER site.

9. ***Phosphorus Dynamics in Urban Streams.***

Phosphorus is the limiting nutrient for plants in most freshwater systems but little is known about phosphorus dynamics at the BES LTER sites. We explored impacts of watershed urbanization on the magnitude and export flow distribution of P along an urban-rural gradient in eight watersheds, using long-term water quality data and lab incubation experiments.

10. ***Concentrations and Effects of Pharmaceuticals Across an Urban Land Use Gradient.***

In spring 2012, Co-PI Rosi-Marshall and Collaborator D. Snow (University of Nebraska) deployed passive samplers for measuring the concentrations of pharmaceutical compounds (including illicit drugs) at six streams in BES. These six sites are a subset of the permanent stream sites that have been extensively measured in the past. During the two week deployment, at four sites, we also deployed passive diffusers of six commonly detected pharmaceuticals downstream of the samplers to measure the effects of these drugs on carbon cycling. We measured the effects of exposure on biofilm primary production and respiration on biofilms. In addition, two undergraduates worked in Rosi-Marshall's laboratory during the summer on possible pharmaceutical interactions and the effects of short-term exposures of drugs on biofilms.

11. ***Urban Stream Continuum.***

The following projects are a result of leveraging efforts of Co-PI C. Welty at the Center for Urban Environmental Research and Education at UMBC to establish a research program tied to the BES LTER related to advancing the understanding of the urban hydrologic cycle and related biogeochemical cycles. These projects support staff, students, and faculty. The goal of the work is to build an end-to-end system to synthesize geospatial data, sensor data, special field synoptics, mathematical models, and databases to provide predictive capability of the movement of water and its constituents in urban areas, with a specific application to the Baltimore metropolitan region.

Project number	PI	Title	Project period	Relies on LTER data	Relies on LTER infra-structure
DGE-0549469	Welty	IGERT: Water in the Urban Environment	8/1/06-7/31/13	yes	yes
EF-0709659	Welty	CNH: Collaborative Research: Dynamic Coupling of the Water Cycle and Patterns of Urban Growth	9/1/07-3/31/13	yes	yes
CBET-0854307	Welty	Integrating Real-Time Chemical Sensors into Understanding of Groundwater Contributions to Surface Water in a Model Urban Observatory	8/1/09-7/31/13	yes	yes
DEB-0948944	Whitmer	ULTRA-Ex: Collaborative Research: Urban Sustainability and Push-Pull Drivers of Residential Change: Washington, DC, Baltimore, Maryland, and the Chesapeake Bay	8/15/10-1/31/13	yes	yes
EAR-1039831	Welty	MRI: Acquisition of Liquid Water Isotope Analyzer Capability for Advancing Hydrologic Research in the Baltimore Ecosystem Study LTER	10/1/10-9/30/13	no	yes
CBET-1058038	Welty	Collaborative Research, WSC-Category 2: Regional Climate Variability and Patterns of Urban Development - Impacts on the Urban Water Cycle and Nutrient Export	1/1/11-12/31/15	yes	yes

C. Welty has supervised staff and students in carrying out the following activities during the reporting period:

- Graduate student Aditi Bhaskar has completed a coupled groundwater-surface water model of the Baltimore Metropolitan region and will be coupling with an urban growth model as a next step, to predict the interaction of water availability and urban growth to 2030 in the Baltimore region. Grad student Zhengtao Cui has completed a particle tracking nitrate transport code and is currently applying it to urban riparian areas to quantify the effects of urban stream downcutting on groundwater flow paths and denitrification potential, in collaboration with Co-PIs P. Groffman, S. Kaushal, and Collatorabor A. Gold. Grad student Alimatou Seck has built a coupled groundwater-surface water model of the entire Chesapeake Bay watershed to enable quantification of groundwater flow paths and travel times across physiographic provinces. Programmer Michael Barnes is carrying out ultra fine-scale coupled groundwater-surface water modeling for urban headwater streams (less than 1 sq km) to quantify the effect of development patterns at the neighborhood scale on the hydrologic cycle. Undergraduate students Kelsey Weaver and Roxanne Sanderson have assisted with processing of input geospatial and temporal data for the modeling efforts.

- Real-time water quality sensors were deployed at six stream stations in Dead Run, Baltimore, MD beginning in October 2010 and have been maintained until present, with the exception of being brought in during winters 2010-11 and 2011-12. Satlantic SUNA nitrate optical sensors and YSI 600-LS specific conductance and temperature sensors were placed in locked housings at USGS sites where water level data was already being recorded. Spectral analysis of the high-frequency sensor data as well as the BES long-term weekly chemistry data was the subject of Jason VerHoef's MS thesis. A manuscript on this work was submitted to Water Resources Research on 7/24/12. In summer 2012, existing sensor assemblies were supplemented with new dissolved oxygen, turbidity, and PAR sensors. The additional data will be used to add to the data required for writing a paper on stream metabolism. Students Dakota Smith and Julia Miller carried out these deployments.
- A water isotope analyzer for BES LTER projects was deployed at UMBC within the reporting period; initial results for the isotopic content of Baltimore precipitation and streamflow have been obtained.

12. ***Urban Water Cycle***.

Ongoing work supported by NSF CNH and WSC grants (C. Welty, PI) involves research on the urban water cycle, including comparisons of watershed hydrologic response associated with varying patterns of urban development and stormwater management; geomorphology and hydraulics of the urban riparian zone, and the influence of urban infrastructure on flow patterns and residence times in urban streams.

The elements of our work on the CNH project, "Collaborative Research: Dynamic Coupling of the Water Cycle with Patterns of Urban Growth," fall into three primary categories: hydraulic modeling; spatial analysis of watershed characteristics; and analysis of watershed hydrology. In the current phase of work we are focusing on storm-period response and on comparisons across watershed scales and across the spectrum of development ages and patterns. In order to assess characteristic response signatures we have developed a library of quickflow hydrographs for most of the fifteen gage sites in the Gwynns Falls watershed, and we have extracted unit hydrographs for short-duration rainfall pulses and for simple storms of longer duration that activate a larger fraction of the available contributing area. We have also extracted data on rainfall and runoff depths for a larger population of storms within the study watersheds. We have conducted and are continuing to conduct analyses of hydrograph shape and precipitation-runoff mass balance. Potential controls include watershed size and shape, impervious cover, natural and artificial drainage density, dominant soil types, spatial distribution of saturated surfaces, and percent of drainage area controlled by stormwater management. Using the spatial data layers available to us (e.g. Figure 5) and analytical tools applied within the ArcGIS environment, we have worked on quantifying watershed characteristics and examining the relationships between watershed properties and watershed response to storm events. As part of this analysis we employ simplifying assumptions to investigate the extent to which comparative patterns of storm response can be explained by the topology of the augmented urban drainage network (modified as described below) before invoking other controlling factors such as stormwater management. Data sets we have produced will be made available to other investigators working at the watershed scale.

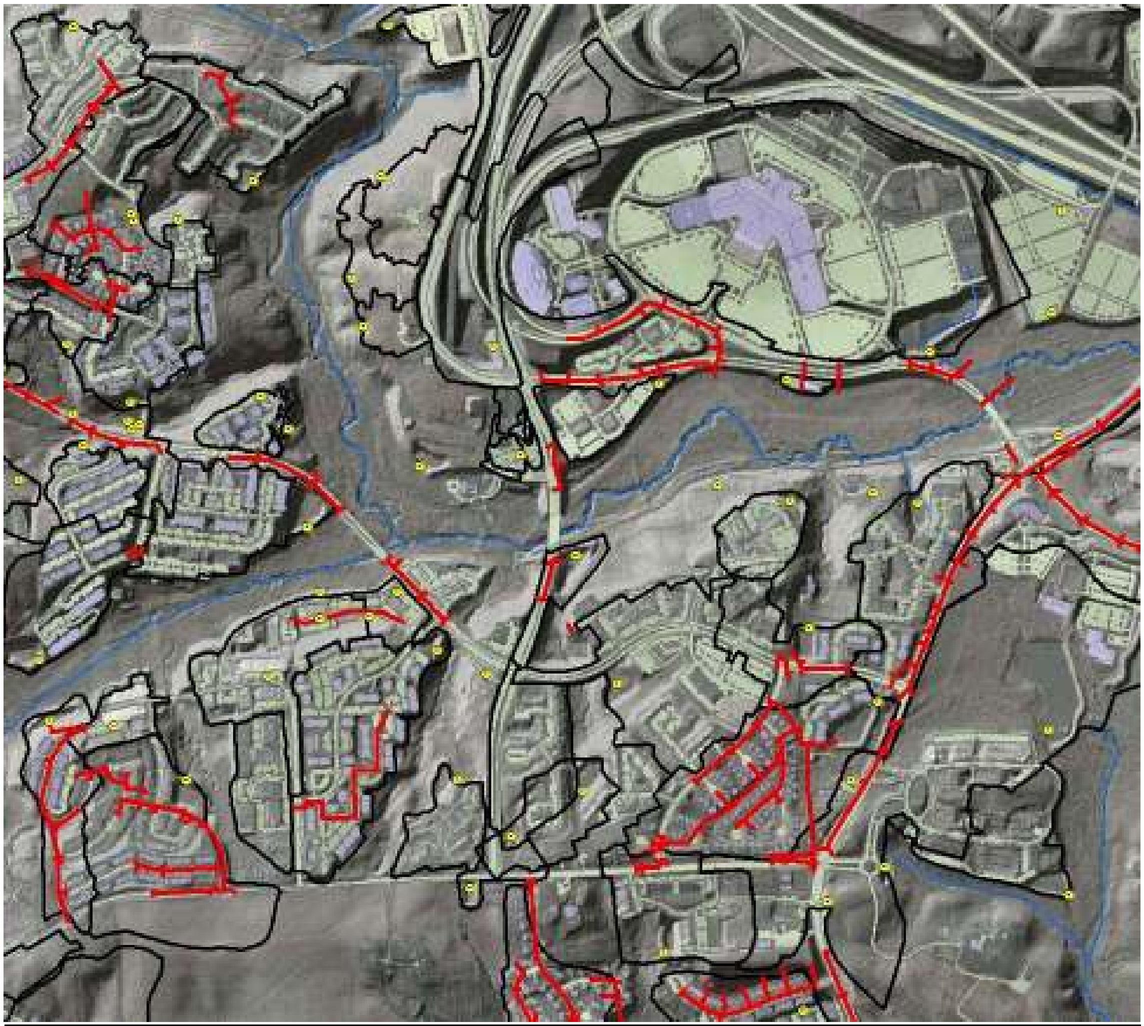


Figure 5. GIS coverages for a portion of the Red Run tributary watershed including LiDAR topography (shaded relief), buildings, roads, hydrography (blue), storm drains (red), stormwater management facilities (locations marked by yellow dots) and areas draining to stormwater management facilities (black rectangles).

Hydraulic modeling

We have completed the work begun in previous years on the use of a 2-dimensional depth-averaged hydraulic model to develop stage-discharge relationships (*Lindner and Miller*, 2012). These are used in the process of converting recorded water levels into flow data for stream gages. Three stations required particular attention this year. The three stations are the DR-5 tributary of the Dead Run watershed (drainage area 1.53 km^2); the Red Run tributary of Gwynns Falls (drainage area 18.7 km^2); and the Horsehead Branch tributary of Gwynns Falls (drainage area 4.75 km^2). All three are of interest to other BES investigators. In all three cases, channel instability associated with sedimentation and/or scour and with the effects of debris-jam obstructions required channel resurvey and modification of the hydraulic models and additional simulation, as well as QA/QC to correct stage data in order for the hydrologic data to be useable for research purposes.

Watershed delineation

As was described in the annual report covering the period ending December 2011, delineation of watershed boundaries and the accompanying flow path and network datasets are important for determining the landscape characteristics that control hydrologic response. These datasets are commonly derived from Digital Elevation Models (DEMs), which are grid based topographic representations of landscape elevation. The contributing area to a watershed outlet is used to summarize watershed characteristics such as soil types, drainage densities, land cover characteristics, and the spatial distribution and average depth of rainfall. The DEM derived network datasets such as flow direction, flow accumulation, and flow length grids are used to determine flow path properties through the landscape in a watershed. These datasets are key pieces for hydrologic modeling to predict timing and magnitude of hydrologic responses at various points throughout a watershed (Beven, 2001).

The topography of the urban landscape is strongly modified by urban development. In intensely developed parts of the landscape, urban infrastructure may dominate topographic patterns and surficial flowpaths. Headwater channels are often buried (Elmore and Kaushal, 2008); grading and excavation of residential subdivisions, major roadways, and parking lots and large-lot commercial and institutional properties, alter local elevations, gradients, flow directions, and locations of drainage divides. Subsurface storm drains in watersheds of relatively gentle gradient may not honor topographic drainage divides, routing water from one side of the divide to the other and effectively capturing the drainage from an area that otherwise would flow into a different set of channels. Watershed delineation as carried out previously was based on existing topographic data and hydrography data sets. We have found it necessary to link the storm-drain network data layer to the channel network in order to determine where the functional drainage divides are located. We have chosen to delineate an augmented drainage network that includes roads and parking lots (Figure 6), which for the most part are impervious and contribute flow directly to storm drains and then to channels. Network properties such as drainage density have very different values when the drainage network is augmented by inclusion of the roads layer.

New watershed delineations were produced in the past year to reflect our improved understanding of the effect of urban development and urban infrastructure on drainage networks, contributing areas and drainage divides. These were produced at multiple pixel scales, ranging between 1-m and 30-m pixels, the latter of which is consistent with the resolution of the USGS National Elevation Dataset and the former of which is the maximum resolution compatible with existing bare-earth LiDAR data available from Baltimore County.

Figure 6. Augmented drainage network for Dead Run DR-5 tributary, created by snapping roads and parking lots to storm drains and surface channels in a binary hydrography layer. Drainage divide is in yellow.

Drainage network topology and wetness index

Additional geospatial analyses have been carried out with the purpose of identifying fundamental watershed properties that may have significance for storm response. Although infiltration dynamics and exchange between surface and subsurface are obviously important, the first set of analyses focus on the topology of the drainage network under conditions associated with urban development. We use the augmented drainage network in order to derive width functions, or probability density functions for flowpath distance upstream of the watershed outlet. The frequency distribution of travel distances, which can be represented as a frequency distribution of travel times with simple assumptions about characteristic velocity, is a common element of studies that employ the Geomorphologic Instantaneous Unit Hydrograph or GIUH (Rodriguez-Iturbe and Valdes, 1979) to characterize watershed hydrologic response as a function of drainage network topology and watershed shape (e.g. Rinaldo et al. 1994, D'Odorico and Rigon, 2003). It has been observed that the shape of the width function is not necessarily skewed left as is the case with a typical hydrograph; but by assuming different characteristic velocities for hillslope overland flow as compared with channel velocity, a left-skewed pdf resembling a simple storm hydrograph is generated. In order to generate width functions for comparison across our different study watersheds we tested ratios of channel:hillslope velocity between 10 and 1000. These are used to assess whether we can capture aspects of the comparative watershed response using simple assumptions that depend only on watershed shape and network topology. A modified form of the width function may be generated by assuming that pixels in the augmented drainage network upstream of a stormwater management structure will have a reduced velocity or delayed response. We have a working algorithm that will be used to explore whether the effects of stormwater management structures on the shape of the watershed hydrologic response can be simulated with equally simple assumptions.

Even in a watershed that is >=40% impervious, there is a large portion of the watershed where varying depths of the water table or variable extent of surface saturation may trigger activation of additional surface flowpaths and additional contributing area. One metric for assessing how watershed contributing area changes with the degree of saturation is the topographic wetness index (Beven and Kirkby, 1979), developed as part of the TOPMODEL system and defined as $\ln(\alpha/\tan\beta)$ where α is the upslope contributing area per unit contour length and β is the local gradient. Thus larger contributing areas and gentler gradients, such as are found in riparian zones, will have greater propensity to be saturated, and the areas most likely to generate runoff (without making any assumptions about actual subsurface flowpaths or geographic distribution of hydraulic conductivity) can be ranked based on values of the index. With increasing degrees of saturation, larger saturated areas will be connected to the drainage network and contribute flow to the storm hydrograph. In order to examine the spatial patterns of the wetness index for our study watersheds we used DEM data of 5m and 10m resolution derived from interpolation of LiDAR topography; we also used NED 1/3 and 1/9 arc-second topographic data as described above, with roughly 9-m and 3-m spatial resolution. Algorithms from version 5.0 of TAUDEM (Tarboton and Mohammed, 2010) were applied to generate GIS coverages of the spatial pattern of the wetness index over the Gwynns Falls watershed for comparative purposes. Additional algorithms are available that make use of information on soil properties as well as topography; we have not yet tested these as we are still in the early stages of assessing how the information derived from the spatial pattern of the wetness index across our spectrum of watershed conditions may be relevant to an understanding of watershed hydrologic response.

<u>Hydrograph analysis</u>

We have continued this year with our comparative analysis of watershed hydrologic response, utilizing discharge records from our own stream gages (DR1 through DR5, Horsehead Branch, Red Run) and other stream gages in the Gwynns Falls watershed that are operated by USGS (Maidens Choice Run, Powder Mill Run, Dead Run at Franklintown, Scotts Level, and mainstem Gwynns Falls gages at Glyndon, Delight, Villa Nova and Carroll Park). Several of these are core stations for the Baltimore Ecosystem Study. We are mining these records for individual storms and analyzing storm hydrographs in conjunction with precipitation time series derived from the HydroNEXRAD 1-km^2 15-minute precipitation archive. We have nested watersheds at several levels: three levels of nesting within the Dead Run watershed (1-2 km^2, 5-6 km^2, and 14 km^2), nesting of four watersheds with drainage areas of

5-20 km^2 upstream of the Gwynns Falls at Villa Nova station (84.1 km^2), and nesting of the Villa Nova site, representing the upstream suburban ~50% of the watershed, within the larger Gwynns Falls at Carroll Park (171 km^2), which is drained by additional, more urban tributaries including Dead Run, Powder Mill Run, and Maidens Choice Run, as well as several ungaged sewersheds. We are working with Josh Cole, Environmental Data Manager for CUERE, to import a library of storms from the HydroNEXRAD database into ArcGIS in order to allow us to characterize the dynamic spatial and temporal patterns of precipitation in individual storms in conjunction with analyses of hydrograph responses in our target watersheds. The 2000-2009 HydroNEXRAD database provided by the Princeton team is now being supplemented by data from the 2010 and 2011 calendar years. Data for these two years have not yet been bias-corrected but we will be able to perform our own bias correction for individual storms using data from the network of CUERE precipitation gages. This increases the number of storms available for quantitative analysis including basic mass balance on precipitation and runoff as well as analysis of timing and shape of hydrograph response as a function of both precipitation and watershed characteristics.

Hydrograph analysis involves baseflow separation using a recursive digital filter approach (Arnold and Allen, 1999; Szilagyi, 2004; Eckhardt, 2005; Schwartz, 2007), implemented by G. Lindner in MATLAB. The resulting quickflow trace captures the runoff response of our study watersheds to storm events. Using the quickflow trace for each gage site, we have analyzed storm hydrographs and hyetographs to identify “pulse” events representing the shortest coherent time period of significant precipitation (generally >= 10 mm) that results in a hydrograph response, and we have selected a group of such events for each watershed, integrated the volume of quickflow over the hydrograph timebase, and converted each hydrograph into the equivalent hydrograph for 1 cm of runoff. These were then compared and averaged to generate unit hydrographs representative of watershed response to a pulse event triggered by a rapid pulse of precipitation in an urban watershed, generally with 75% of the rainfall occurring in 30 minutes or less. We also selected a separate set of storms for most of our gages that represented precipitation duration closer to the characteristic response time of the watershed, in order to determine to what extent the response to a storm that wets most of the watershed produces a different signature from the short-duration pulse response. We generated “unit” hydrographs for both conditions and summarized information about the time lag between the center of mass of precipitation and both the hydrograph peak and center of mass of runoff. We also calculated the shortest time interval containing at least 50% of the total unit quickflow runoff, characterized by Smith et al. (2005) as a measure of basin dispersion; this can also be compared with an equivalent statistic for the storm-period rainfall. We have been extracting precipitation and runoff depth statistics for a larger population of storms in each watershed in order to assess the frequency distribution of runoff ratio, temporal trends within watersheds, and comparisons across watersheds of differing characteristics.

13. ***The Urbanizing Watershed Continuum***.
This framework provides a fresh, interdisciplinary view of urban streams through time and in their full three dimensional complexity. It opens the door to useful ways to think about urban ecohydrological systems as well as conceptualize research projects. It also has great implications for how urban water systems might relate to green infrastructure. A website and blog is being established to make this new concept available to a broad audience. It is also being used as one of the foundations for the Science Synthesis project.

14. ***Science Synthesis: A New Stormwater Management Paradigm***.
The understanding of aquatic ecological systems has evolved over the decades, revealing an ever-greater complexity and dimensionality in what are now seen as ecohydrological systems. What we have learned likely has relevance in the way stormwater management in urban landscapes are designed. These BMPs (best management practices) are currently undergoing major changes, moving from a limited number of traditional engineering-based designs, with basins draining large areas, to numerous smaller “micro-BMP” facilities that make use of vegetation (rain gardens, low impact development, green roofs, etc.). It is clear that the application of what we know about eco-hydrological processes and fluxes in urban streams and forests has great potential to advance and enhance emerging stormwater management facilities by expanding the array of tools available in their design, as well as raising the awareness of the availability of additional ecological services that could make them more useful, multi-objective entities in the landscape. There are many questions regarding their design, running the gamut from traditional ecological flows and processes to how incredibly complex stormwater systems based on traditional engineering principles can function when combined with a growing tendency toward a “green” infrastructure. More robust and integrated science-based foundations here are crucial to the evolution of effective and sustainable policies, management and regulations for urban water management.

With these questions and objectives in mind, a current US Forest Service effort, funded by the Washington Research and Development Office, is under way at the Baltimore Field Station and University of Maryland Baltimore County to examine the available science and bridge interdisciplinary barriers in the quest for relevant eco-hydrological science and conceptual models. This work will be looking to diverse sources (civil engineering, agroforestry, stream and landscape ecology, hydrology, soil science, etc.) to create a picture of what we know and establish potential cross-connections. Traditional literature reviews and many conversations and meetings are being used to synthesize existing knowledge and connections regarding the application of ecohydrology to stormwater management design.

15. ***Watershed 263 a New Stormwater Management Paradigm***.
We sampled baseflow and stormwater runoff in Watershed 263, an ultra-urban catchment in west Baltimore City that is undergoing restoration aimed at both improving water quality as well as the quality of life in its neighborhoods. The focus was on urban hydrology and described the high baseflow and stormwater concentrations and nutrient, metal, bacterial and other pollutant loads seen in two

15 ha headwater storm drain catchments within WS263 that were sampled from 2004 to 2010.

16. ***Organic Matter in Urban Streams***.
Leaf litter inputs are an integral part of the trophic structure of many stream ecosystems and litter breakdown is a key ecosystem function in forest and stream ecosystems. Litter inputs and breakdown processes determine how much of these inputs are available, and in what form, for habitat and food resources both for local and downstream biota. Breakdown rates and associated decomposition processes are likely more complex and less researched in urban streams than forest streams, so we measured litter breakdown rates in a forest stream (Baisman Run, 381 ha, 1 % impervious surface cover) and a suburban stream (Gwynns Falls, 1066 ha, 17 % impervious surface cover.) Both of these are sites of the Baltimore Ecosystem study Long-term Research project in Baltimore County, MD. Litterbags of senesced American Sycamore (*Platanus Occidentalis*, Platanaceae) and London Planetree (*Platanus acerifolia*, Platanaceae) were used, with the Sycamore leaves coming from riparian sites from along a spatial urban-rural gradient, and Planetree leaves from two pairs of urban-suburban micro-gradient sites. These two species were of interest because these are closely related, both genetically and historically, with *P. acerifolia* replacing Sycamore trees in the urban landscape through planting. Leaf litter of both species, native and non-native, therefore become part of the urban stream trophic structure, with *P. acerifolia* litter transport being facilitated by stormwater drainage infrastructure.

Activities: Urban Metacommunity

1. ***Relationship of Trees and Soils to Nitrogen Cycling.***
The goal of this project is to determine the relationship between tree species, the substrate on which they grow, and their efficiency in nitrogen cycling. The hypothesis is that species of trees are adapted to most efficiently cycle nutrients including nitrogen on the particular geologic/soils substrates on which they generally grow. If this proves to be the case, then small stands of trees planted on appropriate substrates throughout the Chesapeake Bay watershed might prevent a large amount of nitrogen from entering the Chesapeake Bay. Trees and soil samples are being collected in a small mostly forested watershed, Baisman Run, in northern Baltimore County, adjacent to the Gwynns Falls watershed.

2. ***Urban Tree Metacommunities*.**
One goal of sustainability plans in urban environments is to maintain or improve biodiversity. Biodiversity in this context is often poorly defined, but often assumed to focus on local diversity in remnant habitat and/or disturbed space. However, the substantial spatial disaggregation of the urban landscape created by variation in human valuation of land generates a complex template on which ecological communities respond. One of the goals of BES Phase III is to extend and refine basic ecological theory to understand how biodiversity is maintained at multiple scales in urban ecosystems. The context for conservation and sustainability is that, in the built environment, how biodiversity is maintained is not completely

understood without adequate understanding of how people value biodiversity within and among habitats, and how they interact directly and indirectly with the proliferation of preferred versus neglected species. A detailed analysis of 209 woody plant communities in Baltimore, Maryland was undertaken that included not just remnant and disturbed habitat but also those located on residential lots, commercial lots, parks and vacant lots, revealed significant variation in local diversity.

3. ***Assembly of Urban Pond Metacommunities*.**
The complex urban landscape is hypothesized to mediate both the local and regional factors that influence species diversity of ecological communities. Despite rapidly expanding urban centers, we know far less about the mechanisms that shape urban communities, despite the evidence that highly organized assemblages thrive in the built environment. To begin to understand how urbanization can shape biodiversity patterns, we focused on two regional constraints, source pool composition and dispersal, and one local environmental factor. We hypothesized that the urban regional species pool is relatively depauperate, and therefore constrains the number of species available for colonization. Furthermore, high fragmentation of the urban landscape should limit dispersal, which should result in a decline in local diversity. Finally, degradation in habitat quality should serve as an environmental filter, eliminating species, and reducing diversity. To test the relative importance of these local and regional factors, we manipulated each in a full-factorial design to estimate the response of zooplankton communities in pond mesocosms. Mesocosms were inoculated from either three rural or three urban stormwater ponds, and dispersal maintained in half of the mesocosms for twelve weeks. Local water quality was degraded by introducing road deicer as sodium chloride, a contaminant of rising local concern.

4. ***Human Management Explain Urban Metacommunity Properties*.**
There is great value to conducting basic ecological research in urban environments. Classical ecology, however, has avoided human-dominated landscapes in favor of “pristine” or “more natural” landscapes, and traditionally characterized human inputs to natural systems as a “disturbance.” It is becoming clear, however, that characterizing all urban habitats as ‘disturbed’ does not accurately describe the complex patterns of species turnover that result from how humans influence the interacting processes that shape community assembly. Herbaceous plant surveys were conducted in Baltimore, MD, during the summer of 2009 in habitat patches that fall along a gradient of human management from “low” (the building footprint section of vacant lots) to “medium” (remnant back gardens in vacant lots). These sites were resurveyed during the summer of 2012, and the management gradient was extended to include a “high” category of human management (active community gardens). Using a metacommunity framework, we hypothesize that humans influence both local and regional processes, and that this results in patterns of species diversity and composition that are not well explained by models that do not take human impacts into account. We asked 1) does the spatial partitioning of species diversity vary between management groups? and 2) How does species diversity vary with environmental distance and geographic distance between sites?

5. ***Long-term Monitoring of Riparian Plant Community*.**
In collaboration with BES Co-PIs Chris Swan at UMBC and Vanessa Beauchamp at Towson University, we started to assess riparian ecosystems in unrestored ad restored sites in Baltimore City and County. This work will form a baseline dataset for long-term monitoring of riparian plant community assembly process and soil development. We are conducting soil sampling and analysis. In summer 2012 we sampled all of the sites, prepared, and partially analyzed the soil samples. Data we collected so far are texture, pH, LOI, C and N. Elemental analysis is underway.

6. ***Soil CO_2 Efflux Measurements*.**
We continued soil respiration measurements at the Cub Hill site. Research Associate Jong Ahn Chun has developed a model to calculate CO_2 efflux using CO_2 concentration gradients, and compared these results with measured data. The measurements were terminated in July 2012. The next step is data analysis.

7. ***Urban Mosquito Monitoring – Ovitraps*.**
BES Co-PI LaDeau collected data in Baltimore, MD to test the hypothesis that urban breeding habitats support fewer mosquito species but greater abundances of WNV vector species. In 2010, 2011 and 2012 ovitraps were set out to collect weekly samples from egg-laying mosquitoes along the urban gradient from Baltimore City to a rural, reference watershed in the County.

8. ***Monitoring an Invasive Mosquito Species and Community Education*.**
This is a Joint Research-Extension project to advance management of the invasive Asian tiger mosquito among urban environments with diverse socioeconomic and cultural backgrounds. Neighborhoods have been chosen in Baltimore and Washington, DC to reflect some continuity in land cover but differences in economic status. In Baltimore, we are initially targeting Franklin Square and Union Square neighborhoods (with the guidance of Parks & People Foundation and local community leaders). In the initial pre-treatment year of this work, surveys of all accessible mosquito breeding habitat in yards (DC) or across neighborhood blocks (Baltimore) will be conducted to identify species and densities of larvae present. In Baltimore we have targeted six replicate blocks across two neighborhoods. As a primary goal here is to assess the utility of activities aimed at motivating residents to manage mosquito populations in their own yards, we use a combination of interview surveys and mosquito breeding surveys in a before-after intervention design.
Associated Grant/Funding: P. Leisnham, S.L. LaDeau, and G. Hager. Management of the Asian tiger mosquito among socioeconomically diverse urban neighborhoods through community-based education and involvement. Northeastern IPM Agency, $36,000, expires 7/2014.

9. ***Mosquito Production in Storm Water Structures*.**
BES Co-PI LaDeau and postdoctoral researcher Robbie Johnson have surveyed ~35 storm water structures across Baltimore County for mosquito community composition and abundance. Seventeen have been visited twice during the 2012 season and the full food web community has been sampled. This work is broadly defined to identify the association between engineered storm water hydrology

(intended and actual) and the production of human biting mosquitoes. We will explicitly test hypotheses about predator release, resource competition, and evaluate pest species tolerance of pollution in this system.
Associated Grant: S.L. LaDeau, J. Cole, .and E.J. Rosi-Marshall. Collaborative Research: Trophic regulation and support of mosquitoes: An ecosystem approach to pest emergence along an urban gradient. NSF Ecosystem Science, $150,000; 5/1/11 4/30/13.

10. ***BES Bird Monitoring Project***.
The BES Bird Monitoring Project is a breeding bird survey designed to find out what birds are found in the breeding season in Baltimore and where. Our monitoring efforts will show associations among block group socioeconomic variables, land cover, land use, and habitat features with breeding bird abundance, to provide information for land managers on possible consequences of land use changes on bird communities. A distinguishing feature of the bird monitoring at BES LTER, relative to other urban bird work, is the capacity for long-term monitoring of features at multiple scales through links to other parts of the project. Different processes influence habitat for birds at different scales, e.g. ongoing household level human decision-making at lot scale vs. block or neighborhood scale abandonment/re-development. Our project seeks to understand how these processes impact bird occurrence, abundance, and composition differ at the lot, block and neighborhood scale.

Over the past year, findings from the all previous years of bird monitoring were compiled and contributed to a synthesis project conducted by a working group on urban biota at the National Center for Ecological Analysis and Synthesis (C. Nilon and P. Warren are co-leaders of the working group). The working group aims to answer the question, “What makes an urban biota?” by collecting bird and plant species lists from cities around the globe. Baltimore is one of 54 cities worldwide where bird data are available.

Activities: Educational

1. ***KidsGrow.***
We have continued to develop and provide curriculum and teacher professional development to the Parks & People Foundation KidsGrow After-School Program. In the 2011-2012 school year, the KidsGrow “My City’s an Ecosystem” Curriculum was located at two sites; Franklin Square Elementary and Patterson Park Public Charter School. A total of 120 students participated in the program across both sites. Four complete modules were taught: Ecology, Decomposition, Water and African American history. In addition, the last two months of the school year were spent engaged in art and ecology projects with a focus on urban agriculture. The students took field trips Great Kids Farm and went camping. Franklin Square students saw nature art on the trail in the Gwynns Falls Park and participated in a nature crafts activity after their hike. The fall semester was spent on a rich exploration of urban ecosystems and decomposition. Students developed an understanding of urban ecosystems by studying their schoolyard and neighborhood

ecosystems and investigating the causes of decomposition. During the spring semester, students learned about water in the city and were engaged in the ecological history of their communities

2. ***Research Experience for Teachers (RET).***

RET teachers work closely with a scientific mentor, developing and carrying out an independent research project. Some of the RETs who began research in the summer of 2011 continued their research into summer 2012. In the summer of 2012, one additional RET Fellow joined the BPESL project. Jocelyn Virtudes began her Research Experience for Teachers work in June 2012 and is scheduled to complete her project by spring of 2012. Ms. Virtudes, a science teacher at Independence School Local 1 in Baltimore City, is conducting research with mentor scientist Ken Belt, (USDA Forest Service). Her research focuses on micro storm water management best practices.

3. ***Baltimore Ecosystem Study Teachers' Institute***.

The Teacher Institute participants and RETs from the summer of 2011 participated in five one-day professional development sessions during the 2011-2012 school year. The teachers taught lessons presented to them during the summer 2011 workshop, providing students with the abilities to attain positive outcomes in terms of content knowledge, skills, citizenship practices and attitudes towards science and become part of a learning community of students, scientists, teachers, and education researchers in Baltimore and across the nation, that is interested in defining and fostering environmental science literacy.

In the summer of 2012, our Institute attendees participated in a summer workshop that represents the first portion of a year-long Baltimore Ecosystem Study Teachers' Institute. The workshop, a 7.5 day professional development program focusing on urban ecology and placed-based teaching methods, was designed specifically for participants in the Baltimore Partnership for Environmental Science Literacy funded by the National Science Foundation. These middle and high school science teachers received training in environmental science research and teaching techniques, and learned about the project's education research into student thinking and learning. These teachers will continue to participate in this Partnership during the 2012-2013 school year by attending five one-day professional development sessions.

4. ***Education Research: Investigations in Ecology Teaching***

Responsive Teaching Study: We are now analyzing the results of two years of intensive professional development with teachers, and research with the teachers and their classrooms.

5. ***Integration of Science and Art***.

In 2012 BES furthered the link between scientific efforts being conducted through the project to parallel work in the arts through the establishment of an Artist-in-Residence program. The first BES Artist-in-Residence is Lynn Cazabon, a photographer whose project entitled "Uncultivated" investigates the relationship between wild plants and the built environment.

6. ***Moving Field Guides***.

- Rock Creek Park Moving Field Guide. April 10, 2012. Participants: 25. Dance Exchange artists including Cassie Meador and five others; US Park Service Education Specialist Maggie Zadorozny acted as a naturalist partner on the event in addition to BES Co-PI Dr. Mark Twery; Heidi McAllister of the USDA Forest Service Conservation Education program participated. Hannah Kerr at the Sandy Spring Friends School and Marla McIntosh of the University of Maryland partnered to engage middle school and college students in engineering and the plant sciences in the Moving Field Guide to create an intergenerational experience. Participants walked throughout the Milkhouse Ford area of the park, and under the leadership of naturalists and dancers, learned about migration, invasive species, the ecosystem the creek provides, and how the park has changed over time. Through collaboration with the naturalists, Dance Exchange company members choreographed dances with the students inspired by the natural world and the principles of stewardship the naturalists conveyed.
- Glen Echo Park Moving Field Guide. April 11, 2012. Participants: 10. Twery and Dance Exchange artists conducted a Moving Field Guide at Glen Echo Park through a partnership with Meredith Foster, Education and Program Manager, and the Living Classrooms program at Glen Echo. US Park Service staff also consulted in the planning of the Moving Field Guide, during which Glen Echo Staff and Dance Exchange company members worked with approximately ten members of the Takoma Park Young Activists. The Young Activists meet weekly to debate and discuss the pressing political, economic, social, and environmental issues of our time and engage in global citizenship work. Dr. Twery acted as the lead naturalist on the project and National Park Service Ranger Kevin Patti added his knowledge of the park's history and nature.
- Ivy Creek Park Moving Field Guide. May 10, 2012. Participants: 12. The fourth Moving Field Guide conducted over the course of the *How To Lose a Mountain* community engagement tour took place at Ivy Creek Park in Lynchburg, VA with elementary school students from Sheffield Elementary School. Dance Exchange company members worked with Dr. Twery and Dr. Greg Eaton, a Master Naturalist and the Director of the Claytor Nature Study Center of Lynchburg College to tailor a Moving Field Guide suitable to a younger population while focusing in on the particular dance and environmental studies interests of the students. Randi Twery, a counselor at the school, and two science teachers, also acted as facilitators for this Moving Field Guide.

7. ***Parks & People Activities***.

BES partner Parks & People Foundation (PPF) conducted the following activities:

- Worked with federal, state, and local government and community-based organizations to develop and implement restoration plan for 935-acre storm drain watershed (Watershed 263) incorporating eleven neighborhoods in West and Southwest Baltimore to demonstrate impact of greening strategies on quality and quantity of storm water runoff and quality of life. Collaborated with the US Forest Service and Baltimore City DPW to collect data for assessing impact of restoration activities. Measurable change has occurred in Watershed 263 with regard to improved water quality and quality of life.

- Building Resources and Nurturing Community Health & Environmental Stewardship (BRANCHES) youth corps carried out projects in urban forestry and environmental restoration training, and work force development employment programs in public high schools and public housing sites in Baltimore City. BRANCHES provided economically disadvantaged youth with training and employment experience to develop useful job skills that lead to long-term opportunities in related professions. Started transfer of youth corps model to Howard County READY program and enhanced partnership with National Park Service to transfer this model to Chesapeake Bay watershed.
- Provided environmental education enrichment in Leakin Park on the Gwynns Falls Trial for 250 Baltimore City rising 2nd, 3rd & 4th graders participating in the PPF SuperKids Camp 6-week reading enrichment summer program.
- Provided environmental education enrichment after-school at Patterson Park Public Charter School for 135 youth, grades K-8.
- Provided environmental education enrichment after-school to 55 students at Franklin Square Elementary Middle School.
- Provided Project BLUE (Baltimore Lessons in Urban Ecosystems), an environmental education program that uses curriculum developed by Parks & People Foundation, BES and USDA-Forest Service scientists to fifteen 6th grade students after-school at Harlem Park Elementary Middle School.
- Provided Tree Ecology lessons during schoolyard tree plantings in partnership with TreeBaltimore to approximately 400 students at nine school sites.
- Participated in the Baltimore Green Schools Network. Continued to lead the action committee on Schoolyard Greening and attended and provided input on the Green Teaching action committee.
- Mary Hardcastle of PPF is the Northeast Regional Liaison for the MSDE funded implementation of the Maryland environmental literacy plan.
- Served on the nature playspace and community health working groups of the Maryland Partnership for Children in Nature.
- Strengthened relationships with local universities through the Urban Resources Initiative. Maintained relationship and outreach to Baltimore City Community College to provided field experiences and professional development for their Environmental Sciences major. Increased the number of interns working on natural resource management issues with the Baltimore City Department of Recreation and Parks.
- Provided schoolyard habitat and Maryland Green School training for teachers assessing the use of schoolyards as outdoor classroom; conducted evaluation that revealed an increase in usage and maintenance of schoolyard habitats and an increase in tree canopy and habitat installations over academic year.
- Organized outdoor experiential activities for youth at Winans Meadow, a trailhead of the Gwynns Fall Trail in Leakin Park.
- Developed and carried out community organizing activities with Blue Water Baltimore and Baltimore Community Foundation for community-based storm drain watershed restoration projects in Baltimore City, working with community-based organizations and engaging community residents to improve water quality and ecosystem function.
- Aided BES scientists and staff in developing relationships with local public agencies, non-profits, community groups and residents.

- Strengthened existing relationships with Baltimore City agencies and officials. Coordinated consultation between BES scientists and Baltimore City Office of Sustainability, Department of Public Works and Department of Recreation and Parks.
- Organized and provided technical and logistical support to BES scientists, graduate assistants and research.
- Contributed data for the Baltimore City Commission on Sustainability 2011 Annual Report.

Outreach

Outreach is fundamental to the mission and success of the Baltimore Ecosystem Study. As a research question, we want to know how people develop and use knowledge of the metropolitan area as an ecological system. In addition, we have learned from the literature and from a ten year social science and community restoration research program in Baltimore predating the LTER effort, that informing and working with communities and constituencies is required to conduct ecological research in the city and suburbs. Hence, we conduct a wide variety of community and educational activities.

1. ***BES Annual Meeting and Community Open House/ Greening Celebration***.

Formal public outreach is accomplished through the BES Annual Meeting, attended by scientists, educators, community members, and decision leaders from the Baltimore region as well as by BES researchers and educators. The evening Open House is held annually in conjunction with the Parks & People Foundation's Annual Greening Celebration. Parks & People has been instrumental in attracting Baltimore residents and local and federal government leaders to the Open House and Greening Celebration. Over time, the number of attendees at these functions has grown. Attendance at the Annual Meeting in 2011 was approximately 125 and there were 200+ attendees at the Greening Celebration. Parks & People Foundation presented awards to individuals and groups for their local community gardens. Three additional quarterly research meetings are held during the year on various topics.

2. ***Educational Outreach.***

- Co-PI Kathy Szlavecz and her soil group participated in the US Science Fair Expo, Washington DC Convention Center, JHU (IDIES), in March 2012. Their exhibit included hands-on activities on carbon cycle and CO_2 sensing.
- Co-PI Kathy Szlavecz and her soil group hosted and mentored two high school seniors from Friends School in summer 2012. They participated in field and lab activities including earthworm and soil sampling, soil processing and data entry.
- Kathy Szlavecz gave a lecture for high school physics teachers (Quarknet Workshop, JHU Physics and Astronomy Dept): Sensor Systems to Measure the Carbon Cycle, July 31, 2012.

- Co-PI Mary Cadenasso gave a lecture on Urban Ecology showcasing the Baltimore LTER to an undergraduate class in "Introduction to Environmental Horticulture" (ENH 1) in December 2011 at the University of California, Davis.
- BES Co-PI Gordon Heisler of the US Forest Service presented two guest lectures, 80-minutes each, to the urban forestry class at the SUNY College of Environmental Science and Forestry on urban physical environment—including vegetation effects on air temperature, human comfort and health, and ultraviolet radiation—using examples from BES research. (February and March 2012).
- BES Co-PI LaDeau worked with leaders in the Franklin Square and Union Square Community Associations to introduce the mosquito projects and advise residents that researchers would be in the area. Additionally, G. Hager kept the broader Watershed 263 Advisory group informed. The project was described in local newsletters and through email lists.
- Co-PI Ken Belt was invited by Baltimore City Community College(BCCC) instructor R. Danforth to participate in the UMAB-BCCC Workforce Opportunities workshop, August 24, 2011. At this student-focused event held at the UMD Biotech Park in Baltimore Belt provided advice to students, info on BES-USFS, internship opportunities, etc. BCCC students are from an underserved community.

3. ***Field Trips and Tours***.

- BES Education Team Leader Alan Berkowitz and Ecology Education Program Leader Bess Caplan organized and led a tour of BES research sites for the Pathways MSP Project Annual Meeting in Baltimore on September 20, 2011.
- BES Co-PI Ken Belt presented urban hydrology results, concepts at UMBC roundtable, and participated in a field tour at the BES Rognel Heights stream sampling station, for Dr. Heikki Setälä, soils ecologist and professor of urban ecosystem studies at the University of Helsinki, and several urban ecology visitors, on November 21 2011.
- Ken Belt participated in a field tour for USFS, NSF, local government officials (Carroll Park, WS263, Parks and People, etc) and did a short presentation at the Carroll Park USGS gage on BES stream research on July 19, 2011.
- BES Project Director Steward Pickett and K. Belt conducted a Tour of BES field sites as part of the Society for American City and Regional Planning History (SACRPH) conference meeting in Baltimore; visited Carroll Park, Gwynns Run, WS263, Crimea Mansion, November 20, 2011.

4. ***Other Outreach***.

- Material generated as part of the BES has been presented to local stormwater managers and state agency personnel with specific interest in nitrogen sources in urban areas. Expertise and advising is actively being provided to Chesapeake Bay Program on watershed modeling, and to local NGOs (e.g. Chesapeake Bay Foundation).
- Co-PI Geoff Buckley gave a speech entitled, *Tribute to Fred Wilson Besley*, at the Maryland DNR dedication of the Fred W. Besley Demonstration Forest in Linkwood, Maryland on April 23, 2012.

- Co-PI Mary Cadenasso presented a seminar at NCEAS entitled "Ecosystem services and environmental justice as tools to achieve urban sustainability" in December 2011.
- USGS is one of the local representatives for BES on the new Federal Urban Waters Initiative, Patapsco Watershed pilot area work group that initiated work in 2011.
- David Newburn presented findings on the potential impact of the new septic regulation on the number of remaining development rights on the remaining undeveloped parcels in Baltimore County. This presentation was given at the Baltimore County Department of Environmental Protection and Sustainability (EPS), July 12 with high-level agency staff in attendance from the Department of Environmental Protection and Sustainability; Department of Permits, Approvals, and Inspections; and Office of Planning of Baltimore County.
- The Bird Monitoring Project recruited its first volunteer, a Baltimore City resident who learned about the project through the BES website. Mr. Fishel participated in the project by collecting and recording data for the first winter bird count.
- BES Co-PI Emma Rosi-Marshall moderated the Hydrofracking Forum at the Cary Institute of Ecosystem Studies, Millbrook, NY in April 2012.
- K. Belt continued to serve on the Board of Directors for the Maryland Water Monitoring Council (MWMC). Also served on the Monitoring and Assessment Committee, and the Annual Conference Planning Committee. These activities with the MWMC are in the context of providing a link to the scientific community to resource managers, in particular as a representative of the USDA Forest Service and the BES LTER.
- K. Belt continued to participate in the Area I SWAP (Small Watershed Actin Plan) steering committee mtg, representing BES The goal is to develop a SWAP for the Baisman Run catchment (a BES catchment) as well as the surrounding Beaver Dam Run and Oregon Run (Br) watersheds; K.Belt was invited to join the SC by Erin Wisnieski, DEP (Baltimore County Dept of Environmental Protection).

Presentations, Posters and Websites Considered Outreach Activities

Presentations

Barnes, M., C. Welty, and A.J. Miller. 2012. High-resolution distributed watershed modeling of urban landscapes in the Chesapeake Bay Watershed using ParFlow. 2012 Chesapeake Community Modeling Symposium, Annapolis, MD. 21-22 May.

Barnes, M., C. Welty, and A.J. Miller. 2012. High-resolution distributed watershed modeling of urban landscapes in the Chesapeake Bay Watershed using ParFlow. CUAHSI 3rd Biennial Science Meeting, Boulder, CO. 16-18 July.

Belt, K. 2011. Organic matter and debris in urban streams. Webinar: "How Gross Can You Get-Controlling Gross Solids and Illicit Discharges as Stormwater Management," Center for Watershed Protection, Ellicott City, MD. 5 October.

Belt, K. 2011. Leaves and bugs: Using litterbags in education and stream ecosystem studies. Talk presented as part of a workshop at the 17th Annual Conference of the Maryland Water Monitoring Council, Think Baywide, Act Streamside; Implementing the Chesapeake Bay TMDL, at the Maritime Institute and Graduate School, Linthicum, MD, 2 December.

Belt, K.T., W.P. Stack, and S.S. Kaushal. 2012. Ecohydrological principles: Green infrastructure meets stormwater engineering. Presented at the Roundtable on Urban Ecohydrology Science and Practice Meeting, Philadelphia, PA. 24 July.

Belt, K.T., W.P. Stack, R. Pouyat, K. Burgess, P.M. Groffman, and S.S. Kaushal. 2011. Ultra-urban baseflow and stormflow concentrations and fluxes in a watershed undergoing watershed restoration (WS263). Presented at the BES LTER Annual Meeting, Baltimore, MD. 19-20 October.

Belt, K.T., W.P. Stack, R.V. Pouyat, K. Burgess, P.M. Groffman, W. Frost, S.S. Kaushal, and G. Hager. 2012. Ultra-urban baseflow and stormflow concentrations and fluxes in a watershed undergoing watershed restoration (WS263). Presented at the Stormwater Symposium, Baltimore, MD. 19-20 July.

Bhaskar, A., C. Welty, and R.M. Maxwell. 2012. Evaluation of the interaction between urban development and water availability using a distributed watershed model. 2012 Chesapeake Community Modeling Symposium, Annapolis, MD. 21-22 May.

Bhaskar, A. and C. Welty. 2012. On the relationship between storage and streamflow in urban watersheds. CUAHSI 3rd Biennial Science Meeting, Boulder, CO. 16-18 July.

Boone, C.G. and M. Fragkias. 2012. A re-examination of urban ecosystem services delivery for good urban governance: implications for environmental justice and vulnerability. Planet Under Pressure, London, UK. March.

Boone, C.G. 2012. Environmental Justice and Sustainability. Invited seminar, Georgetown University. March.

Carrera, J. 2012. Re-imagining parks for the 21st century city. City Parks Alliance International Conference. New York, NY. 14-17 July.

Cole, J., J. Miller, and C. Welty. 2012. Experience with implementing an off-the-shelf system for hydrologic data management. CUAHSI 3rd Biennial Science Meeting, Boulder, CO. 16-18 July.

Cui, Z., C. Welty, and R.M. Maxwell. 2012. Coupling nitrogen biodegradation with a particle-tracking transport model. Presented at the 2012 Chesapeake Community Modeling Symposium, Annapolis, MD. 21-22 May.

Gnagey, M. 2012. A semi-parametric analysis of land prices. Evanston, IL, Midwest Economics Association Annual Meeting. Chicago, IL. March.

Gnagey, M. 2012. Heterogeneous developers, spatial interactions and land development outcomes. Seattle, WA. Agricultural and Applied Economics Association Annual Meeting. Seattle, WA. 14 August.

Groffman, P.M. 2011. Terrestrial denitrification: A tale of misery and woe. Invited seminar, Cornell University, Ithaca, NY. September.

Groffman, P.M. 2011. Urban environmental sustainability. Invited discussion, New York University, New York, NY. December.

Groffman, P.M. 2011. Challenges in assessing nitrogen losses in urban watersheds. Invited presentation. American Geophysical Union Fall Meeting. San Francisco, CA. December.

Groffman, P.M. 2012. Nitrogen dynamics in urban watersheds. Invited seminar. Georgetown University, Washington, D.C. February.

Groffman, P.M. 2012. Urban ecosystem ecology. Invited lecture. Georgetown University, Washington, D.C. February.

Groffman, P.M. 2012. Nitrogen sources and sinking urban watersheds. Institute of Urban Environment, Xiamen, China. May.

Groffman, P.M. 2012. Urban watershed and stream ecology. Invited lecture in course on “Urban Health” at Institute of Urban Environment, Xiamen, China. August.

Haines, S. and B. Caplan. 2011. The Baltimore Partnership for Environmental Science Literacy, improving urban science teaching and learning. National Science Teacher Association Regional Conference, San Francisco, CA. 10 March.

Hom, J. 2012. Urban forests flux studies. Presentation and mobile flux tower demonstration. World Bank Global Environmental Facility (GEF) Climate Change Mitigation Team. Baltimore, MD. 7 May.

Hom, J. and D. Nowak. 2012. Urban forests and carbon sequestration in Baltimore, MD. Center for Climate Strategies. Chinese Academy of Governance Study Tour. Baltimore, MD. 23 May.

Hom, J. 2012. Climate change and urban forests in Baltimore, MD: Reducing emissions and lowering temperatures. Maryland Forest Service, MD State Forester and Central Region Staff. Madonna Ranger Station, MD. 14 June.

Irwin, E.G. 2011.The effects of spatial heterogeneity and regulatory uncertainty on residential subdivision development. Invited seminar. Department of Agricultural and Resource Economics, Oregon State University. 3 December.

Irwin, E.G. 2011. Research on urbanization processes and patterns. Invited presentation. Center for Urban and Regional Analysis, Ohio State University, 7 November.

Irwin, E., Y. Chen, and C. Jayaprakash. 2012. Explaining the persistence of scattered development: A dynamic spatial model of exurban land markets. Selected paper presented at the Allied Social Science Association (ASSA) meetings, Association of Environmental and Resource Economists (AERE) session, Chicago, IL. 8 January.

Irwin, E.G. 2012. Agent-based modeling of exurban land markets. Invited seminar given at the Department of Applied Economics, University of Minnesota. 16 April.

Kaushal, S.S. 2012. Influence of land use, climate variability, and stream restoration on nitrogen dynamics in watersheds. Invited. Smithsonian Environmental Research Center, Edgewater, MD.

Kaushal, S.S. 2012. Land use and climate alter contaminants in drinking water. Invited. Georgetown University Environmental Sustainability Lecture Series. Washington DC.

Kaushal, S.S. 2012. Microbes in the Metropolis. Invited. Towson University.

Kaushal, S.S. 2012. Managing contaminants along the global watershed continuum: Riparian zones to rivers. Invited plenary keynote speaker. National Conference of the American Water Resources (AWRA), Denver, CO. 27 June.

LaDeau, S.L. 2012. Ecological complexity and vector-borne disease: West Nile virus and the phenology of urban mosquitoes. State University of New York, Binghamton. Biological Sciences. 17 February.

LaDeau, S.L. 2012. West Nile virus and the phenology and composition of urban mosquito communities. State University of New York, Albany. Ecology and Evolutionary Biology Series. 10 February.

LaDeau, S.L. 2011. Ecological complexity and disease vectors: Phenology and composition of urban mosquito communities. University of Illinois, Champagne-Urbana, Department of Entomology. 24 October.

LaDeau, S.L. 2011. Ecological complexity and disease vectors: Phenology and composition of urban mosquito communities in Baltimore. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. 19 October.

Miller, J., C. Welty, J. Duncan, and D. Smith. 2012. Preliminary evaluation of water isotopes in Baltimore precipitation and streamflow. CUAHSI 3rd Biennial Science Meeting, Boulder, CO. 16-18 July.

Miller, A.J., C. Welty, E. Bou-Zeid, and J. Smith. 2012. Sensor networks in the Baltimore Ecosystem Study LTER for quantifying urban water and nutrient cycles. NSF ERC MIRTHE Annual Summer Workshop. University of Maryland, Baltimore County. 7 August.

Nowak, D.J. 2012. The color of carbon is green. Ohio State University Nursery Short Course / CENTS Annual Conference. Columbus, OH.

Nowak, D.J. 2012. The value of urban trees. Ohio State University Nursery Short Course / CENTS Annual Conference. Columbus, OH.

Nowak, D.J. 2012. i-Tree: Assessing and monitoring benefits of trees and forests. Leadership Team Meeting of the Maryland Department of Natural Resources. Annapolis, MD.

Nowak, D.J. 2012. National urban forest assessment. Presentations as part of the release of the Future of America's Forests and Rangelands, 2010 Resources Planning Act (RPA) Assessment. Washington, DC.

Nowak, D.J. 2012. Kansas City regional forest assessment. Missouri Community Forestry Council 19th Annual Conference. Blue Springs, MO.

Nowak, D.J. 2012. The future of urban forestry. Missouri Community Forestry Council 19th Annual Conference. Blue Springs, MO.

Nowak, D.J. 2012. i-Tree: Potential integration of urban forestry models and US EPA models and programs. US EPA Region 3 seminar, Philadelphia, PA.

Nowak D.J. 2012. i-Tree: Assessing and monitoring benefits of trees and forests. US EPA webinar.

Nowak, D.J. 2012. Urban forests and their ecosystem services. Arboriculture class lecture, SUNY-ESF, Syracuse, NY.

Nowak, D.J. and S. Maco. 2012. Potential uses and limitations of applying i-Tree in Rio de Janeiro. Urban Forest Workshop of the Rio de Janeiro Low Carbon City Development Program. Rio de Janeiro, Brazil.

Nowak, D.J. 2012. i-Tree: A Tool for measuring the benefits of university campus trees. New York Association of Physical Plant Administrators 6th Annual Conference. Syracuse, NY.

Nowak, D.J. 2012. National urban forest health monitoring. SUNY-ESF Forest Health Monitoring Class. Syracuse, NY.

O'Neil-Dunne, J.P.M. 2012. The high-resolution remote sensing conundrum. Spatial and Temporal Scaling in Continental-scale Ecology Workshop, Boulder, CO. 11-12 June.

Pouyat, R.V. and I. Yesilonis. 2012. Soil response to land development: What stays the same, what changes, and what are the resultant challenges. International Society of Arboriculture Conference & Trade Show. Portland, OR. 11-15 August.

Romolini, M. 2012. Environmental networks and governance of the 21st century sustainable city. Invited Lecture. Georgetown University's "On the Edge: Urban Sustainability" lecture series, Washington, DC. March.

Rosi-Marshall, E.J. 2012. Novel contaminants in aquatic ecosystems: Inputs, fates and potential ecological effects. Invited Seminar Speaker. University of Maryland, Baltimore County, Center for Urban Environmental Research and Education. February.

Rosi-Marshall, E.J. 2012. Outside the scope of the Clean Water Act: The ecological consequences contaminants of emerging concern on freshwater ecosystems. Celebrating 40 Years of the Clean Water Act, A Conference of the Hudson River Environmental Society. March.

Rosi-Marshall, E.J. 2012. Your River on Drugs. North Country Garden Club, Long Island, NY. March.

Rosi-Marshall, E.J. 2012. Your River on Drugs. Keynote Lecture of the AP Biology Readers Conference. (Over 400 AP biology and university professors in the audience.) June.

Seck, A., C. Welty, and R.M. Maxwell. 2012. A 3D integrated surface-subsurface model of the Chesapeake Bay watershed using ParFlow.CLM: Model discretization, initialization and hydrogeologic data. Presented at the 2012 Chesapeake Community Modeling Symposium, Annapolis, MD. 21-22 May.

Seck, A., C. Welty, and R.M. Maxwell. 2012. Distributed hydrologic modeling of the Monocacy River Basin using ParFlow.CLM: Effects of initial conditions on spin-up behavior. CUAHSI 3rd Biennial Science Meeting, Boulder, CO. 16-18 July.

Szlavecz K. 2012. The changing landscape and earthworm communities in the mid-Atlantic region. Invited talk. Smithsonian Institution, National Museum of Natural History, Washington, DC. 30 May.

Szlavecz K., A. Terzis, and A. Szalay. 2012. Life under your feet: Monitoring the soil ecosystem with wireless sensor network. "Current and Future Research in Integrated Soil Sensing," 2nd International Soil Moisture Sensing Technology Conference, Honolulu, Hawaii, 3-7 January.

Troy, A. 2012. The relationship between trees and crime across an urban-rural gradient in greater Baltimore. Invited webinar. Alliance for Community Trees. June.

Van Meter, R. and C.M. Swan. 2012. Tolerance to road salt deicers in chronically exposed urban pond communities. Association of Southeastern Biologists Annual Conference, University of Georgia, Athens, GA.

Welty, C. 2012. Sensor networks deployed in the Baltimore Ecosystem Study LTER for quantifying urban water and nutrient cycles. Invited talk. BES Teacher Workshop. Woodlawn High School. 26 June.

Welty, C. 2012. Use of high-resolution spatial and temporal data to quantify urban water quality and quantity in the Baltimore Metropolitan Region. Invited talk. Baltimore Data Day, University of Baltimore. 12 July.

Wrenn, D.H., E.G. Irwin, and A.G. Sam. 2012. Searching for the urban fringe: Exploring spatio-temporal variations in the effect of distance vs. local interactions on residential land conversion using a conditionally-parametric discrete-time duration model. Agricultural and Applied Economics Association Annual Meeting. Seattle, WA. 14 August.

Wrenn, D. and E.G. Irwin. 2012. Time is money: An empirical examination of the dynamic effects of uncertainty on residential subdivision development. Association of Environmental and Resource Economists Meeting. Ashville, NC. 4 June.

Wrenn, D., E.G. Irwin. 2011. Heterogeneous effects of regulation: A nonparametric model of residential land development. North American Regional Science Council Annual Meeting, Miami, FL. November.

Yesilonis, I. and R.V. Pouyat. 2012. Disturbed environments: Ecological impact & management. 2012 Annual Conference Mid-Atlantic Chapter of the Ecological Society of America, Virginia Tech, Blacksburg, VA. 14-15 April.

Yesilonis, Y. 2012. Emergency response, field health & safety. BES Field Safety and Community Awareness Seminar, Baltimore, MD. 5 June.

Posters

Belt, K., W.P. Stack, R.V. Pouyat, K. Burgess, P. Groffman, and S.S. Kaushal. 2011. Ultra-urban baseflow and stormflow concentrations and fluxes in a watershed undergoing restoration (WS263). 17th Annual Conference of the Maryland Water Monitoring Council, Think Baywide, Act Streamside; Implementing the Chesapeake Bay TMDL, at the Maritime Institute and Graduate School, Linthicum, MD, 2 December.

Belt, K.T., E. Noonan, and P. Groffman. 2011. Stream temperatures in urban watersheds: Interactive effects of riparian cover, scale and the built environment. 17th Annual Conference of the Maryland Water Monitoring Council, Think Baywide, Act Streamside; Implementing the Chesapeake Bay TMDL, at the Maritime Institute and Graduate School, Linthicum, MD, 2 December.

Belt, K.T., E. Noonan, and P.M. Groffman. 2011. Stream temperatures in urban watersheds: Interactive effects of riparian cover, scale and the built environment. Poster presentation, at the BES LTER Annual Meeting, Baltimore, MD. 19-20 October.

Duan, S. and S.S. Kaushal. 2012. Warming increases carbon-nutrient fluxes from sediments in streams across land use. University of Maryland. May.

Holifield, Q., K. Belt, T. Bossiwa, and B. Caplan. 2011. Leaves and bugs: Using litterbags in education and stream ecosystem studies. 17th Annual Conference of the Maryland Water Monitoring Council, Think Baywide, Act Streamside; Implementing the Chesapeake Bay TMDL, at the Maritime Institute and Graduate School, Linthicum, MD. 2 December.

Hom, J., N. Saliendra, M. Patterson, I. Yesilonis, and D. Nowak. 2011. Urban forests flux studies: Reducing carbon dioxide and emissions. Poster and mobile flux tower demonstration. National Association of State Foresters, Baltimore, MD. 18-22 September.

Hom, J., N. Saliendra, M. Patterson, I. Yesilonis, and R. Prenger. 2011. Carbon flux, meteorological and biological monitoring at Cub Hill, Baltimore, MD. BES Annual Meeting, Baltimore, MD. 19 October.

Hom, J., Y. Pan, and K. McCullough. 2012. Modeling nitrogen regulation and emissions trends: Nitrogen retention in the forested ecosystems of the Chesapeake Bay watershed, USA. Beneficial Effects of Healthy Watersheds on Pollutant Fate and Transport: Chesapeake Bay Program STAC Workshop. Claggett Retreat Center, Buckeystown, MD. 7-8 March.

Websites

www.beslter.org – Main website for the Baltimore Ecosystem Study.

http://besdirector.blogspot.com/ – BES Director's Blog which includes research activity and other relevant articles about urban ecology. There is also a link from the www.beslter.org home page.

http://bes-news.blogspot.com/ – BES News online which includes meetings and events, recent publications, research activity news, education news and other relevant news items. There is also a link from the www.beslter.org home page.

http://www.beslter.org/moodle – This site was created specifically to provide information for participants of the Baltimore Partnership for Environmental Science Literacy project. It is used by the BES Education Team, RET teachers, and summer educational institutes for teachers participants as well.

http://beslter.org/perspective/perspective.aspx?action=all-pages&collection=Education – Repository of curricula and other instructional support materials, education-related report and other resources for educators.

http://www.beslter.org/msp – This webpage was created to support the Baltimore Partnership for Environmental Science Literacy, including: participants in the BES Teacher Institute and Research Experiences for Teachers Fellows who participated in the Investigating Urban Ecosystems: Research and Teaching Applications course. It is also used to post resources and assignments for the teachers.

http://www.beslter.org/virtual_tour/index.html – This website page is a virtual tour of BES which provides a detailed description of the research sites. The tour is divided into three themes: Streams, Meteorology, and Permanent Plots.

http://beslter.org/biocomplexity-and-habitable-planet.html – Repository of curriculum and instructional support materials for the BioComplexity and the Habitable Planet project.

http://www.besdata.org – The Open Research System provides partnering research groups and the broader environmental research community a mechanism to share research and data products on the web.

http://www.beslter.org/frame4-page_3h_05.html – Highlights the research on mosquito communities and vector-borne disease risk.

www.beslter.org/biocomplexity – Used to disseminate curricula and study materials including GIS files and software for the BES Biocomplexity K-12 education program.

www.umbc.edu/cuere – Website for BES contributing organization—Center for Urban Environmental Research and Education.

http://his09.umbc.edu/dash/ – In cooperation with the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), CUERE has utilized some long-term BES data to demonstrate the capabilities of the CUAHSI Hydrologic Information System. CUERE has continued to maintain the Data Access System for Hydrology which provides a map-based data discovery and dissemination system where BES data can be visualized and downloaded. In 2008 the BES stream chemistry and long term study plot soil data were added to this system.

http://his09.umbc.edu/BESOD/cuahsi_1_0.asmx?WSDL – CUAHSI WaterML (http://his.cuahsi.org/wofws.html) web service featuring the BES stream chemistry dataset.

http://his09.umbc.edu/BESoil/cuahsi_1_0.asmx?WSDL – CUAHSI WaterML (http://his.cuahsi.org/wofws.html) web service featuring the BES long term study plot soil data.

http://cuereims.umbc.edu/website/bes – This is a clickable Arc-GIS map which includes BES data collection points. A number of features have been added to the map such as the capability to link directly to monitoring site information and directly download stream chemistry data.

http://hydro2.umbc.edu/Precip –From 2008-2010, UMBC Center for Urban Environmental Research and Education upgraded the BES LTER precipitation gage network to include eight dual tipping bucket rain gages, each with wireless telemetry for real-time data streaming. The data are streamed to the TRC at UMBC and automatically uploaded into the CUAHSI Observations Data Model. Programmatic access to this data is provided using a CUAHSI WaterML web service. In 2010, UMBC/CUERE developed a web service client and created this data visualization website to view the data in near real-time. It includes a component for graphing precipitation time series and a component for mapping the rain gage locations.

http://oshydro.umbc.edu/GFhydroNEXRAD – The Hydro-NEXRAD system provides gridded rainfall data spanning 10 years at a 1 sq-km resolution. Princeton researchers calibrated the NEXRAD data to rain gage data on a 15-minute basis for the entire Baltimore region. UMBC/CUERE developed a web-based system based on open source products to automate the spatial extraction and aggregation of Hydro-NEXRAD data. UMBC/CUERE created a spatial database to contain bias corrected Hydro-NEXRAD data from the NWS radar in Sterling, VA (KLWX) from 1999 to 2009. This included design of a web-based interface for the purpose of querying, aggregating, and extracting data from this database. Using this interface, the user can download and visualize the Hydro-NEXRAD data aggregated by watershed as well as a number of temporal resolutions.

www.lifeunderyourfeet.org – This website is dedicated to various aspects of soil research, primarily to developing sensor networks for soil monitoring. We have been collecting data from several sites, among them from urban forests in the Baltimore Ecosystem Study. The data are downloadable from the web. Development and release (alpha version) of Grazor, and new graphical web-interface to view and download soil physical data at various sites in the Baltimore Metropolitan area.

http://www.as.phy.ohiou.edu/Departments/Geography/lter.html – Ohio University webpage describing faculty, students, publications and theses related to BES.

www.fsl.orst.edu/climdb/ – Daily weather data from the BES primary weather station since April of 2000 are posted for free public access on the National LTER database, ClimDB. For comparison, we also post data from two National Weather Service stations, the Baltimore Washington International Airport (BWI) and the Baltimore Downtown station (DMH) at the Maryland Science Center.

http://ecovalue.uvm.edu/ – Based at the University of Vermont, the EcoValue project provides an interactive decision support system for assessing and reporting the economic value of ecosystem goods and services in geographic context.

http://md.water.usgs.gov/BES – USGS webpage describing BES and USGS related activity.

http://nwis.waterdata.usgs.gov/nwis – Historical data for six stream gaging stations supported by BES and many other stations in or near the study area are publicly available at this site. Data available includes historical daily mean discharges, peak flows, field measurements, and stream flow statistics (daily, monthly, annual).

http://waterdata.usgs.gov/md/nwis/current?type=flow – Near real-time streamflow data for five stream-gaging stations supported by BES and many other stations in or near the study.

http://ida.water.usgs.gov/ida/ – Instantaneous Data Archive for retrieval of historical discharge data from water years prior to October 1, 2007 for six stream-gaging stations supported by BES and many other stations in or near the study reach are available for downloading at this site. Future plans are to move all remaining IDA data to NWISWeb sometime in 2013.

http://wdr.water.usgs.gov/ – Annual summary of data for six stream-gaging stations supported by BES and many other stations in or near the study area are publicly available at this site (2006-2012).

http://www.residentialcarbon.org – The site supports community outreach for the Residential Carbon Project, educates landowners about the project, and describes the work to interested parties. Note: Website was mentioned on NPR in a radio interview.

http://www.unb.ca/enviro/research_baltimore.html – Describes the analysis work on Organizational Partnerships and Natural Resource Management in the Gwynns Falls Watershed.

http://nrs.fs.fed.us/urban/utc/ – Description: Urban Tree Canopy (UTC). First UTC prototype was developed for Baltimore and has now been applied to numerous cities in the U.S. Many of the associated publications focus on Baltimore. The website (1) describes the UTC, (2) addresses frequently asked questions; (3) identifies current UTC cities; (4) lists data requirements; and (5) includes relevant publications and products.

ftp://bcftp:bacounty@towson4.co.ba.md.us/deprm – The Oregon Ridge Park Forest Health Assessment and Forest Management Plan. User name=bcftp, PW=bacounty. The Oregon Ridge Park Forest Health Assessment and Forest Management Plan prepared by Mar-Len Environmental Consultants, with assistance from Co-PI Mark Twery. This report is the result of a DEPRM initiative, in collaboration with the

Department of Recreation and Parks, to address forest sustainability of large forested County-owned lands, using the UDSA Forest Service NED method.

http://www.dnr.state.md.us/forests/programs/urban/urbantreecanopygoals.asp Description of needs and methods for assessing existing and potential Urban Tree Canopy; resources describing general and various specific assessments and UTC goals.

www.parksandpeople.org – A section of the Parks & People website (http://www.parksandpeople.org/learn/baltimore-ecosystem-study/) is devoted to the Baltimore Ecosystem Study and the Urban Resources Initiative.

www.ecotope.org/projects/global_frag/ – This is a project page for BES REU-supported research on global patterns of landscape fragmentation in anthropogenic landscapes.

http://ecotope.org/projects/ecosynth/ This site focuses on a user-deployed 3D scanning system for mapping and measuring vegetation biomass, carbon and potentially biodiversity across landscapes.

http://letters-sal.blogspot.com/ – *Letters from SAL*. This site reports on GIS advances from the UVM Spatial Analysis Laboratory, focused primarily on the Baltimore Ecosystem Study. It includes commentary, preliminary results, and software tutorials.

http://weblogs.baltimoresun.com/news/local/bay_environment/blog/2009/03/icy_dilemma_road_salt_taints_s.html – Baltimore Sun's environmental blog: "Icy dilemma: Road salt taints streams, reservoirs."

http://www.itreetools.org/carboncalculator/entry.cfm – The CarbonPlus calculator is a web-based application for informing the public about their carbon emissions and promoting action to reduce those emissions.

http://maryland.netsmartz.biz/ – Temperature Blast – Co-PI Gordon Heisler and BES Educator, Bess Caplan, are working with the Maryland Science Center and the national Association of Science Technology Centers on a project called Communicating Climate Change (C3). The Maryland Science Center C3 project aims to engage members of the public in becoming educated about climate change and as citizen scientists. The citizen scientist role is to collect Baltimore air temperature data to help define the extent and intensity of the urban heat island effect across the city and document urban forest effects on air temperature. Weather data are from the WeatherBug system of school weather stations. The BES sponsored weather station in the forest of Oregon Ridge County Park is one of the stations that contribute data.

http://thepostculture.wordpress.com/2012/04/06/professor-commentary-urban-living-could-hold-key-to-greener-tomorrow/ – This blog submission was written at the request of the Ohio University newspaper.

http://urbanhomogenization.org – Describes new BES-related project on "Ecological Homogenization of Urban America."

http://www.temperatureblast.org/ – Co-PI Gordon Heisler and BES Educator, Bess Caplan, worked with the Maryland Science Center and the national Association of Science Technology Centers on a project called Communicating Climate Change (C3). The Maryland Science Center C3 project aimed to engage members of the public in becoming educated about climate change and as citizen scientists. The web site provides access to a smart phone application that shows air temperature data in Baltimore and vicinity and offers a quiz with answers about urban heat island effects and actions to moderate urban temperatures and reduce energy use. Weather data are from the WeatherBug system of school weather stations. The BES sponsored weather station in the forest of Oregon Ridge County Park is one of the stations that contribute data. BES and NSF are acknowledged as partners on the Maryland Science Center web site.

https://vimeo.com/46270397 – A Moving Field Guide documentation video was released in July 2012 as a promotional to provide background information about the Moving Field Guides, including interviews from Cassie Meador, Mark Twery, other Dance Exchange artists, participants, and partners.

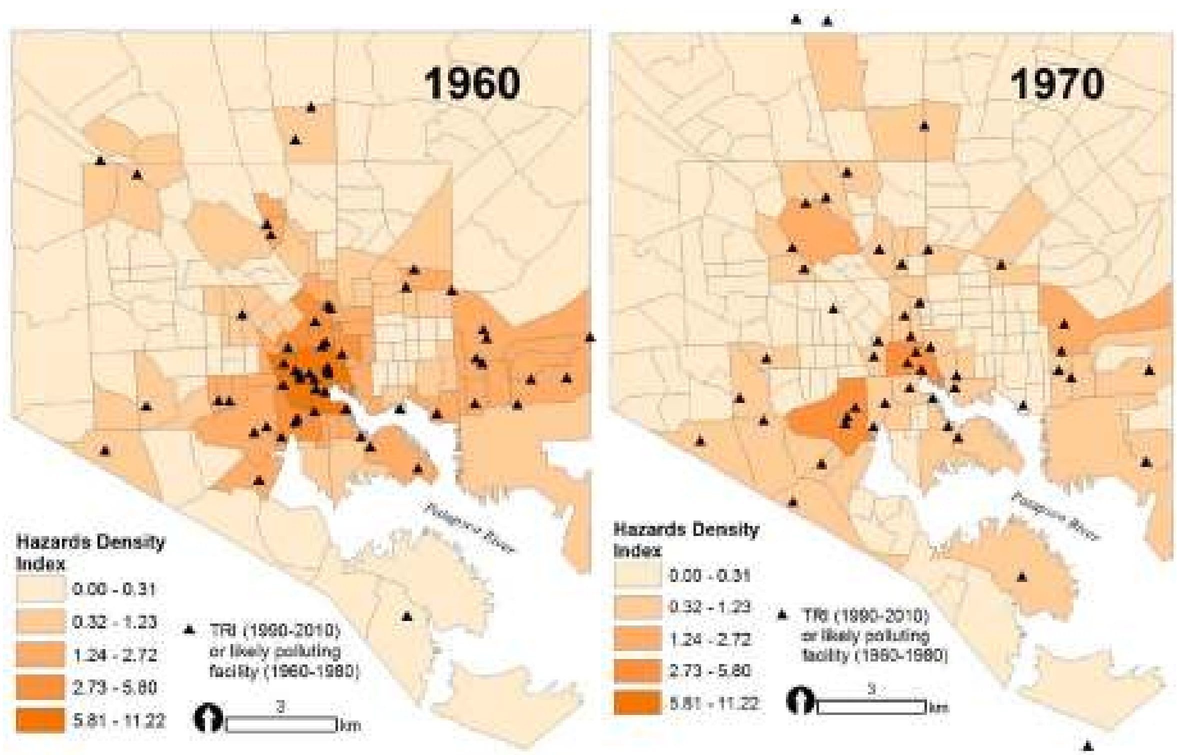
Findings

Findings are presented for each of the three theoretical areas – Locational Choice, Urban Stream Dis/Continuum, and Urban Metacommunity – and for education as a distinct category. In some cases, integrative connections across areas are mentioned.

Findings: Locational Choice

1. ***Environmental Justice: A Long Term Perspective*.**

Density of polluting industry is positively correlated with low-income neighborhoods and renter-occupied housing in 1960 and by 2010 with white, Hispanic, and low educational attainment populations. In general, over time density of polluting facilities shifts from an association with wealth to race and ethnicity while educational attainment remains a significant variable throughout. This study confirms earlier analyses on Baltimore that white neighborhoods are more likely than African-American neighborhoods (1990-2010) to contain polluting facilities but reveals for the first time that educational attainment is also significant.



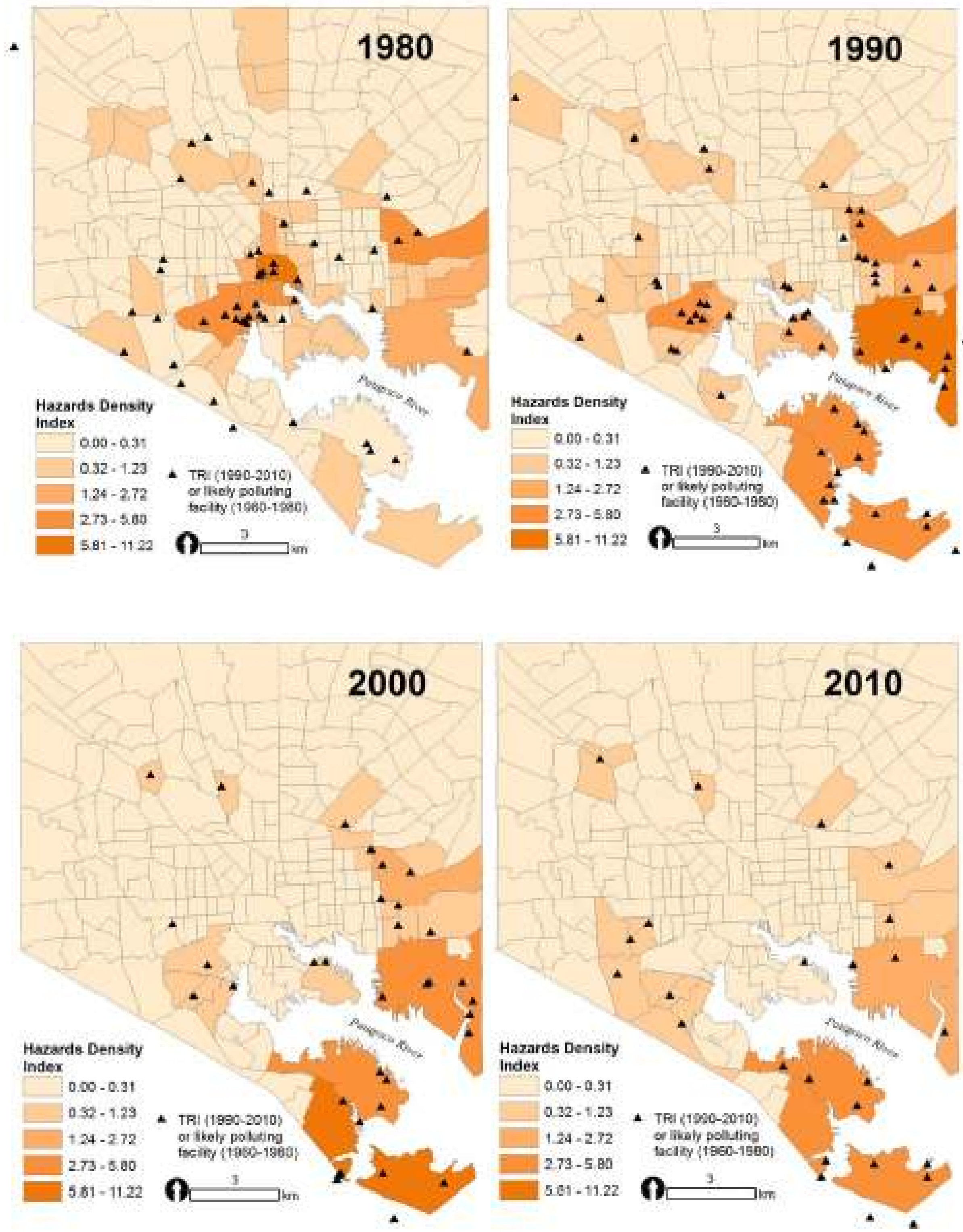


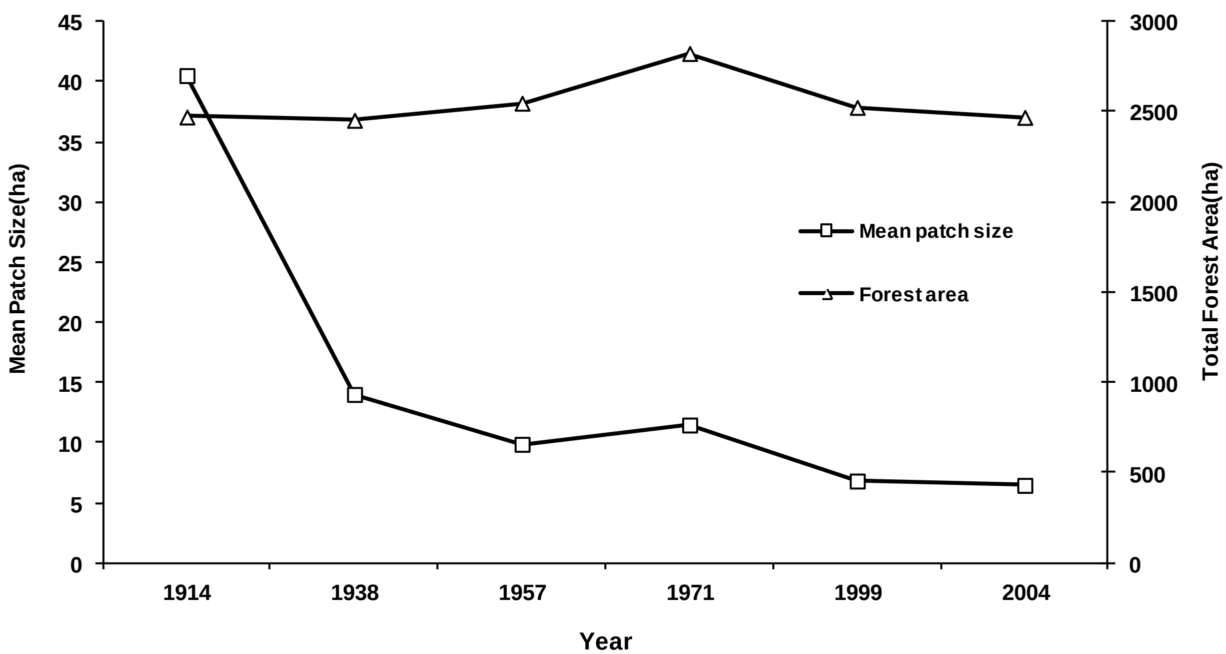
Figure 7. Hazards Density Index for Baltimore City, 1960-2010. The Hazards Density Index measures the density of 800 meter buffers within census tracts. It is a measure of how many polluting or likely polluting facilities are located in and around neighborhoods.

2. ***Environmental Justice.***
Interview data suggest that "greening" playgrounds is generating a lot of interest at schools across the city. The interest is expressed primarily by teachers and students; administrators and school board representatives are somewhat indifferent. Initially supported by the Department of Public works, funding today comes mostly from the Port Authority and private sources interested in offsetting the impact of their construction projects (similar to "no net loss" wetlands banking).

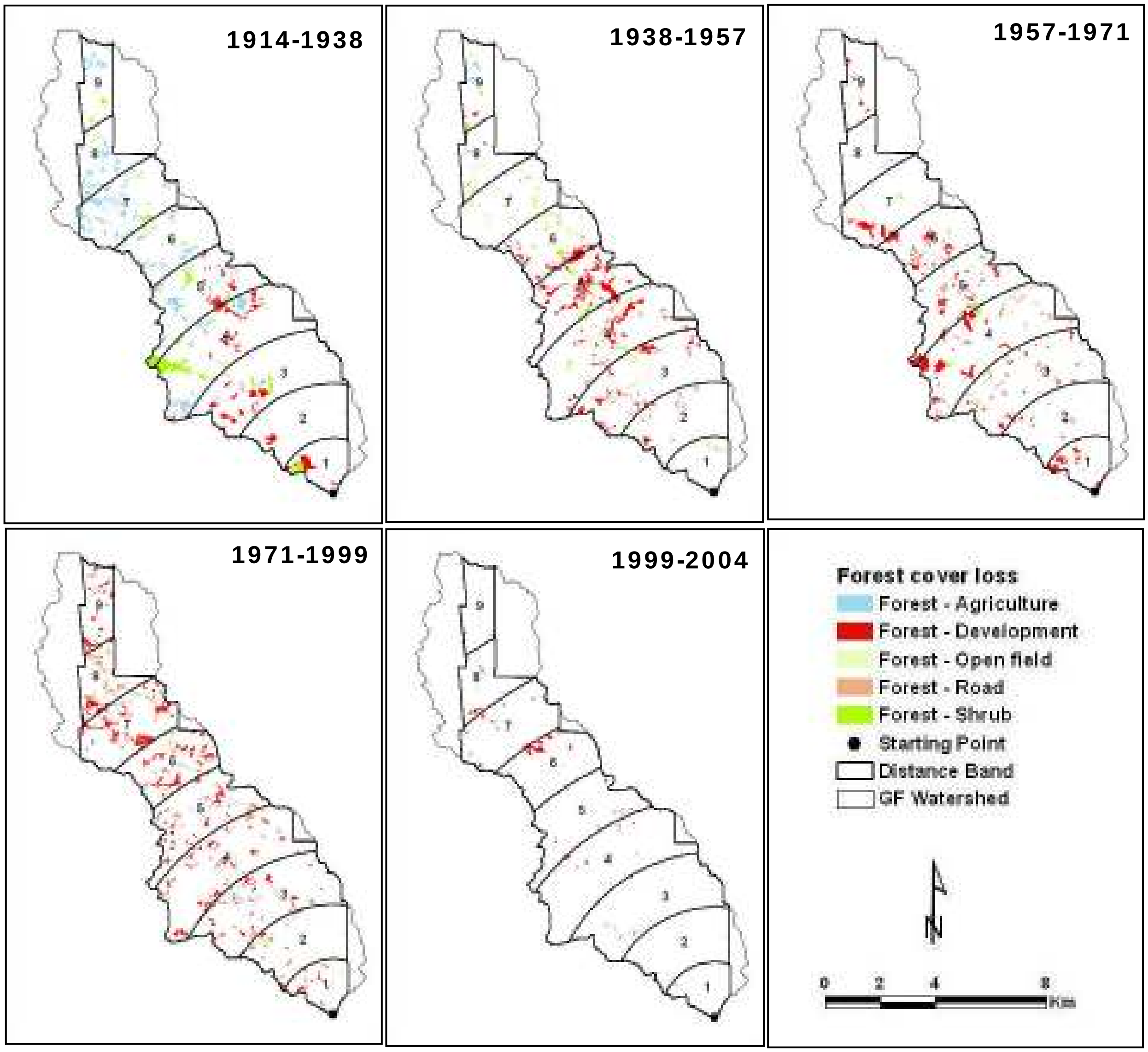
3. ***Urban Composting.***
Grad student Kylie Johnson's research shows that Edinburgh is far ahead of Baltimore and Washington, DC when it comes to diverting compost from the waste Stream. An EU mandate that calls on the city to greatly reduce the amount of waste it sends to the landfill at Dunbar appears to be driving this initiative.

4. ***Change in forest patch structure in the Gwynns Falls watershed.***
Findings on forest cover change by post-doc Weiqi Zhou resulted in publication: Zhou, W., G. Huang, S.T.A. Pickett, and M.L. Cadenasso. 2011. 90 years of forest cover change in the urbanizing Gwynns Falls watershed, Baltimore, Maryland: spatial and temporal dynamics. Landscape Ecology 26:645-659.

- Total forest area remained virtually unchanged from 1914 to 2004 but the average size of patches greatly declined
- Forest cover in the Gwynns Falls watershed has become more fragmented since 1914.



- From 1914-1938 forest cover that was removed was converted primarily into agricultural land uses. Those forest patches closer to downtown Baltimore were converted to development.
- From 1938 through to the most recent data in 2004 the majority of forest cover removed was on land converted to development.



5. ***Modeling Air Temperature Differences Across the Baltimore Region***.
A manuscript is in preparation on modeling air temperature differences in the Baltimore region. The methods developed for Baltimore provided the experience and methodological concepts that are now being applied for Syracuse, New York and New York City.

6. ***Urban Tree Cover Change in the United States***.
National results indicate that tree cover in urban areas of the United States is on the decline at a rate of about 7,900 ha per year or 4.0 million trees per year. Tree cover in 17 of the 20 analyzed cities had statistically significant declines in tree

cover, while 16 cities had statistically significant increases in impervious cover. Only one city (Syracuse, NY) had a statistically significant increase in tree cover. City tree cover was reduced, on average, by about 0.27 percent per year, while impervious surfaces increased at an average rate of about 0.31 percent per year.

7. ***Natural Regeneration in Cities***.

Results for the existing tree populations reveal that, on average, about 1 in 3 trees are planted in cities. Land uses and tree species with the highest proportion of trees planted were residential (74.8 percent of trees planted) and commercial/ industrial (61.2 percent) lands, and *Gleditsia triacanthos* (95.1 percent) and *Pinus nigra* (91.8 percent). The percentage of the tree population planted is greater in cities developed in grassland areas as compared to cities developed in forests and tends to increase with increased population density and percent impervious cover in cities. New tree influx rates ranged from 4.0 trees/ha/yr in Baltimore to 8.6 trees/ha/yr in Syracuse. About 1 in 20 trees (Baltimore) and 1 in 12 trees (Syracuse) were planted in newly established tree populations. In Syracuse, the recent tree influx has been dominated by *Rhamnus cathartica*, an exotic invasive species.

8. ***Spatial Modeling of Residential Subdivision Development***.

A total of 1,784 subdivisions containing 79,731 land parcels were developed between 1960 and 2008 in Harford County. In Baltimore County, a total of 3,757 subdivisions containing 93,667 parcel records were developed between 1960 and 2008. Across Carroll, Harford and Baltimore counties, a total of 7,370 subdivisions containing a total of 208,131 land parcels were developed between 1960-2008, leading to a mix of clustered and scattered patterns of residential development (see Figure 8).

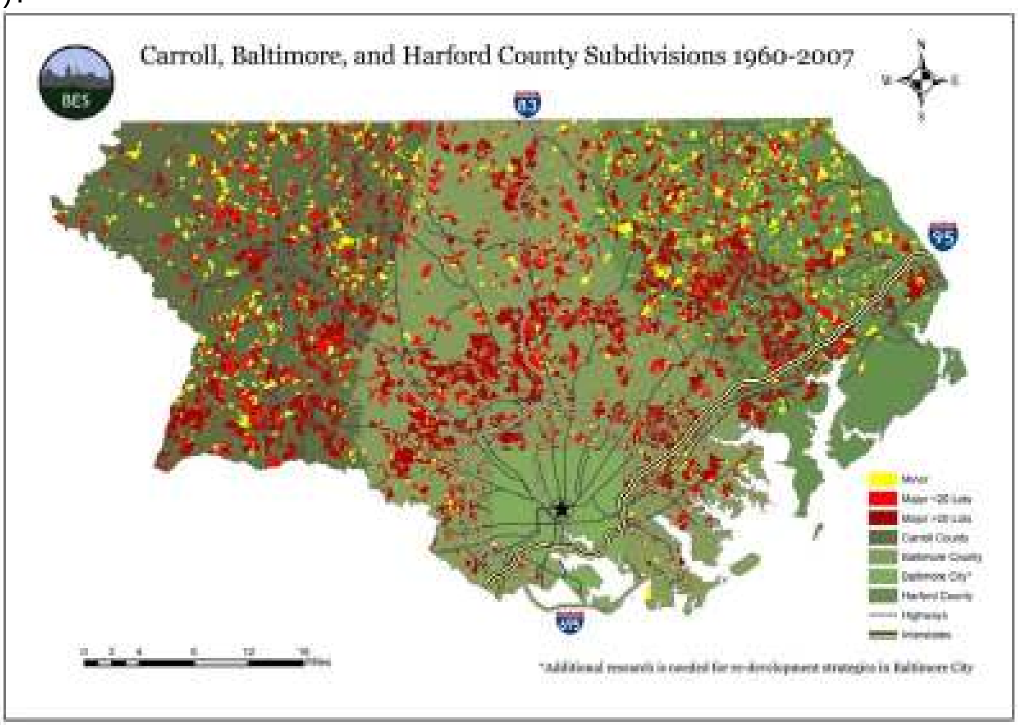


Figure 8. Subdivision development in Baltimore, Carroll and Harford Counties by Decade 1960-2007.

In Carroll County, Wrenn and Irwin found that the residential pattern that emerged over the time period 1995-2007 was extremely scattered and low density. Findings from their analysis are:

- Over 60% of all subdivisions created from 1995 through 2007 were platted in agricultural areas and that of these, 82% were minor subdivision developments of 2 or 3 lots each.
- The length of time that the county spent on reviewing and approving subdivision plans ranged from a minimum approval time of one month to a maximum of 105 months. The wide variation in the length of time required to receive approval of a subdivision plan introduces additional uncertainty for developers that adds to their implicit costs of development. Wrenn and Irwin find that these implicit costs have had a significant influence on the timing and type of development. They estimate that a 10% increase in the expected approval time for all parcels led to a 0.13% reduction in the average probability development and a 5.8% reduction in the average number of lots developed.
- The most substantial difference in approval times is between major (4 lots or greater) and minor (2-3 lots) subdivisions. On average, it took major subdivision developments 22.2 months to be approved and minor subdivision developments 8.9 months to be approved. This substantial difference in implicit costs has had a significant impact on the pattern of development in Carroll County since many minor subdivisions are located in agricultural areas and most major subdivisions are located closer to urban areas. The econometric analysis by Wrenn and Irwin shows that the more expedited review process given to minor subdivision plans increased the probability of minor subdivision development relative to major subdivision development. They show that if this difference in approval times were eliminated, that the predicted probability of development would be the same across the different types of subdivisions. This finding confirms the hypothesis that observed differences in the timing of subdivision approvals has significantly weighted development in Carroll County towards minor subdivision development in agriculturally zoned areas and away from larger major subdivision developments located more densely-zoned areas.
- Policy scenarios in which the approval times of subdivision plans are altered show that a 10% reduction in the approval times for subdivisions located in non-agriculturally zoned areas combined with a 10% increase in the approval times of subdivisions located in agriculturally-zoned areas is predicted to result in the same total amount of subdivisions developed as the status quo (411 compared to 412 for the baseline scenario), but that the lot quantity and spatial distribution of this development would be quite different. Under this scenario, the number of subdivisions in agriculturally-zoned areas would be reduced by 32 (12%) and increased by 31 (20%) in the non-agriculturally zoned areas. The total number of developed lots would increase by 344 (7%). See Table 2. We conclude that a reduction in the relative approval times of major subdivisions can substantially increase the amount of higher density development and reduce the amount of low-density scattered development in the county.

	Predicted Dev.	Predicted Lots	Agriculture Dev.	Non-Agriculture Dev.
Actual Outcomes	397	4577	247	150
Baseline Scenario (95th Percentile)	412	4730	264	148
Cost Increase on All Parcels (1)	353	4117	231	121
Cost Increase for Ag. Only (2)	379	4531	231	147
Cost Increase for Non-Ag. Only (3)	386	4351	265	121
Cost Increase for Ag. and Decrease for Non-Ag. (4)	411	5074	232	179

The cost increases are for a 10% increase in implicit costs on each parcel.
The actual values, which are from the original data, are for comparision.

Table 2. Predicted number of subdivisions and lots developed under baseline and alternative policy scenarios in which the approval times of subdivisions location in agriculturally-zoned and non-agriculturally zoned areas are altered.

In Harford, Gnagey found preliminary evidence of spatial competition among land developers that influenced their location choices and development patterns. Using a sophisticated econometric model that identifies the interaction effect while controlling for other sources of spatial heterogeneity in the data, Gnagey found evidence of a negative interaction effect that is consistent with local spatial competition or congestion that has caused a repelling effect among developers.

9. ***Agent-based Model of Exurban Land Markets***.
We find that a model that accounts for basic market conditions of the exurban land market generates predictions of development patterns that are fundamentally different than those predicted by standard urban economic theory. Transportation costs from an urban center combined with substitution among land parcels and a limited number of households imply that, as distance from the urban center increases, the number of household competing for a location declines and the number of substitutable land parcels available for development increases. As a result, competition among households is more limited for parcels located farther from the city center, implying that households don't have to bid as much for these more remote locations. Given these conditions, we find that leapfrog development and market segmentation emerge since only richer households can afford to move to these more remote locations (Figure 9). These results show that higher income households are able to take advantage of the limited competition in the outer exurban area and will maximize their utility by locating farther away. All other households maximize utility by locating as close to the urban boundary as possible. Over time as competition for location increases in the region, the advantages of locating farther away in the leapfrog zone diminish and converge to the standard prediction of the traditional urban economic model. The extent and duration of leapfrog development varies systematically with the degree of income heterogeneity among households, transportation costs and rate of in-migration. This is a new explanation of leapfrog development—one that explains leapfrog development as the result of limited competition among exurban households with heterogeneous incomes. Because this explanation relies on the relaxing of the long run spatial equilibrium assumption, the only way to model this is with agent-based simulation methods.

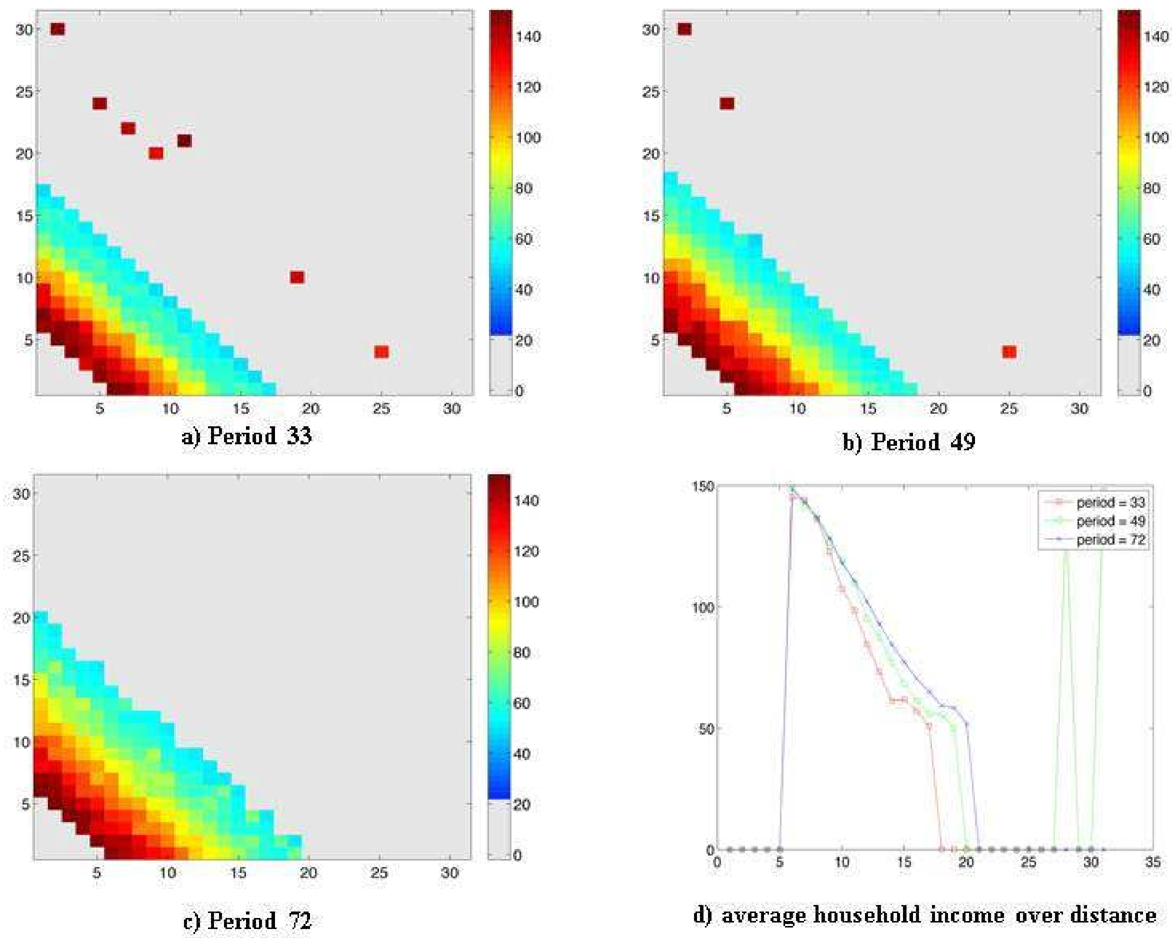


Figure 9. Agent-based model predictions of changes in the pattern of income with urbanization over time (city center is located in the bottom-left corner; the inner exurban boundary is located at distance = 5; leapfrog development occurs in a scattered fashion at distances greater than 21).

10. ***Environmental Determinants of Crime.***

Found a strong statistically significant inverse relationship between crime and tree canopy cover for Baltimore City and County. This relationship was found to be stronger for trees on public rather than private lands. Results were robust to inclusion of a dozen socio-economic control variables and to controlling for spatial autocorrelation. A strong inverse relationship between indicators of yard maintenance and crime at the parcel level was also found. Using geographically weighted regressions, we also found that the relationship between trees and crime is non-stationary, and that in a few neighborhoods in Baltimore City there is a positive relationship between trees and crime, probably because these neighborhoods include many treed interface zones between industrial and residential uses where vegetation is poorly maintained. The research on the relationship between crime and trees in Baltimore, first published in Landscape and Urban Planning gained a significant amount of press and attention due to the finding that trees may lead to lower street crime levels.

11. ***Mapping Transition Zones***.
Our method of statistically designating and mapping transition zones from urban to rural areas was successfully validated against data on population density and buried streams.

12. ***Property values and environmental disamenities***.
Found that proximity to I-170 had a significant negative effect on property values for residential structures in the surrounding neighborhoods.

Findings: Urban Stream Dis/Continuum

1. ***Legacy Effects of Structural Catchment Changes.***
The clarifying concepts reported in the *BioScience* paper (Bain et al) will enhance discussions of legacy effects and improve management outcomes. There are fundamental differences between 1) filling a floodplain with sediment and changing the biotic nutrient assimilation and 2) spilling nitrogen and watching it bleed out over time. These differences will elucidate continued investigations of legacy effects. The next step, quantification of these processes, will allow prediction of feasible hydrologic legacy effects, which can be used in evaluation of a wide variety of hypotheses regarding recent landscape evolution.

2. ***Pond Branch: Geomorphology, Hydrology, and Ecosystem Dynamics Influence on Nitrogen Cycling.***
Seasonal to daily variations in stream nitrate concentrations are closely linked to riparian patterns of groundwater depth and oxygen level in the Pond Branch watershed. Hollows in the Pond Branch riparian zones are responsible for a large amount of nitrogen retention (approximately 1/3 of the total), despite occupying a very small fraction of the total catchment area. This highlights the importance of riparian microtopography and the need to better link observations and models.

3. ***Ecohydrologic Modeling of Stormwater and Associated Ecosystem Processes.***
Workflows developed with iRODS for complex, spatial ecohydrologic models can effectively provide automated access of spatial data from web locations and automated set-up and parameterization. This provides a controlled environment to document, archive and automate model construction, significantly improving efficiency, data and methods documentation and provenance, and allowing researchers to concentrate on higher level analysis.

4. ***Streamflow Monitoring—Urban Hydrologic Networks and Reference***
The primary USGS product is a continuous data stream, which is published annually (http://wdr.water.usgs.gov/), and with most station data available in near real time (http://waterdata.usgs.gov/md/nwis/current?type=flow). Final water year 2011 discharge data for stream gages in the Gwynns Falls and Oregon Ridge areas of Baltimore County and Baltimore City were published in June 2012, and indicated annual mean flows that were generally larger than long-term averages based on

the full periods of record (i.e. the 2011 water year was more wet than the long term averages). Until mid to late August of 2011, available data were indicating a drier year, based on long-term averages. However, Hurricane Irene (August 27-28, 2011) and Tropical Storm Lee (September 5-9, 2011) produced significant flooding in parts of the region that increased the annual mean discharges for most stations to above average, and at some stations, produced record or near-record peak flows. 2012 water year discharge data are still provisional as of mid-August 2012, but are generally indicating a drier than normal year based on long-term averages.

The Minebank Run investigation indicated that physical restoration of the stream channel led to reduced lateral erosion on the stream banks, but sources of fine sediment still exist in the watershed based on pebble count data that indicated fining of the channel bed after completion of the restoration project. Much of the post-restoration geomorphic variability of the channel was due to alternating patterns of sediment storage and removal, and shifting of the channel thalweg, as opposed to channel degradation and widening, and lateral erosion from receding cut banks observed prior to restoration. An analysis of boundary shear stress in the study reach indicated that larger increases in mean velocity were required during storms to initiate sediment transport after the stream channel was restored (Doheny and others, 2012).

5. ***The Urban Stream Syndrome***.

Long-term monitoring of riparian water tables shows that urban stream syndrome leads to lower and more variable water tables (Figure 10). Urban and suburban riparian zones consistently have lower water tables than the forested reference site, and more seasonal fluctuation as well. The forested reference site has a water table approximately 30 cm from the soil surface – typical for riparian wetlands, with relatively little seasonal variation. An interesting exception was during the drought of 2002 which caused the water table to drop to nearly 80 cm.

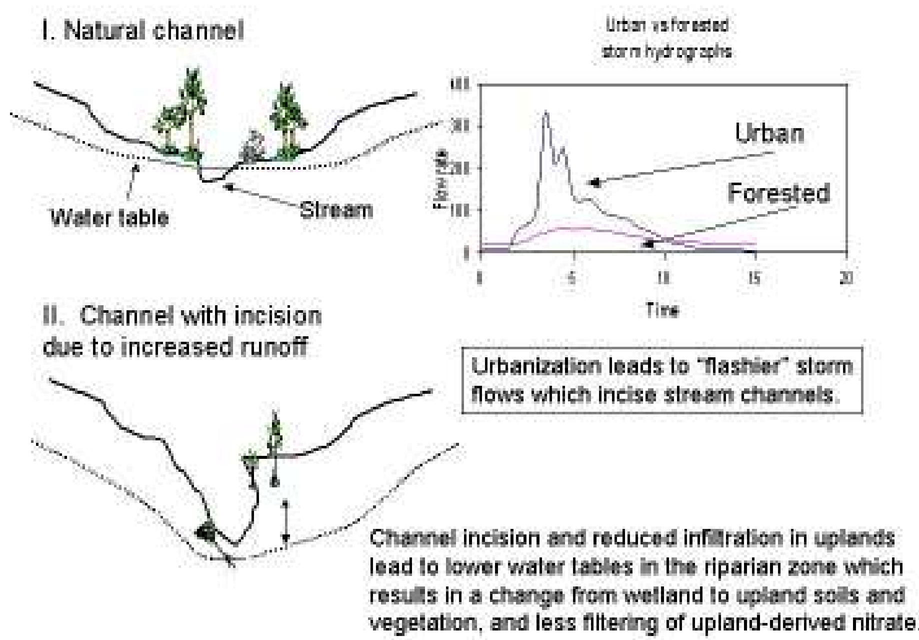
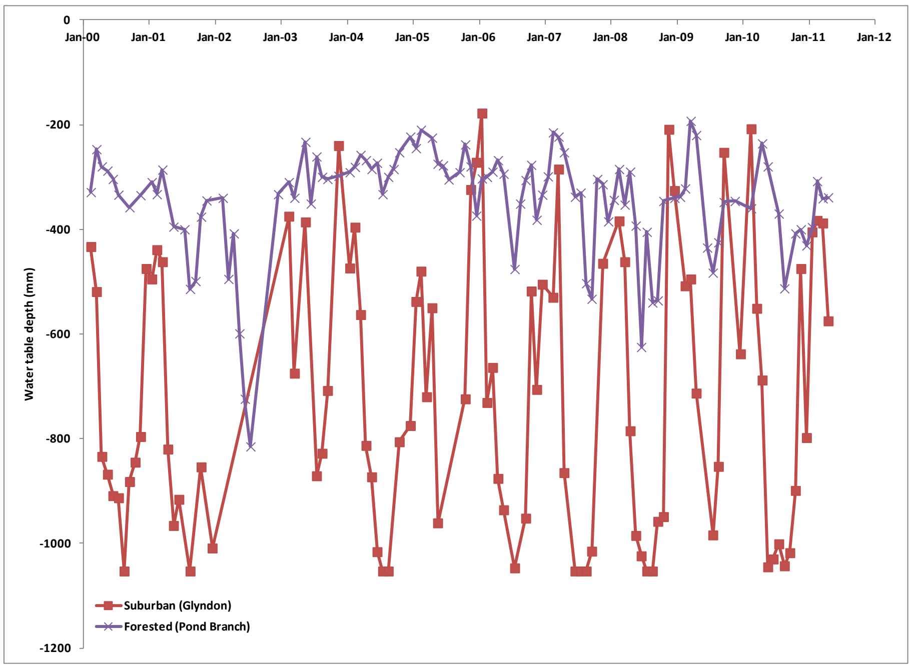


Figure 10. The urban stream syndrome.

The hydrologic changes in the riparian zone are accompanied by chemical changes. Levels of nitrate and phosphate have been consistently higher in the urban and suburban riparian zones than in the forested reference site.

The long-term water table and groundwater chemistry data (recently updated and highlighted on the BES WWW site) are now serving as a platform for new modeling and measurements as part of an NSF funded Water Sustainability and Climate grant led by BES Co-PI Dr. Claire Welty at the University of Maryland, Baltimore County. We are making direct measurements of riparian, hyporheic and stream denitrification and linking these to models and measurements of evapotranspiration and groundwater flow paths and geomorphic changes in the stream channel. The effort is an excellent example of how long-term data catalyzes multi-disciplinary research to address complex questions related to sustainability.



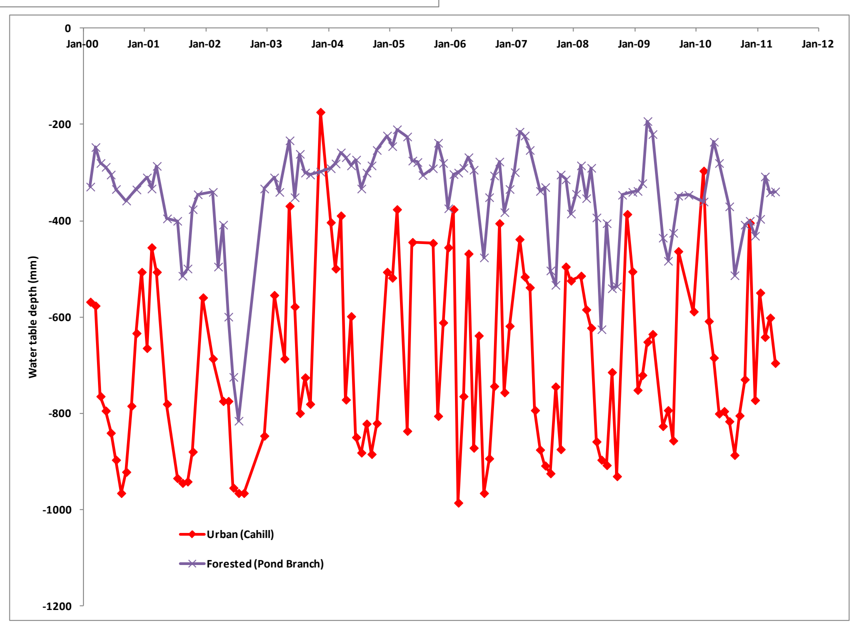
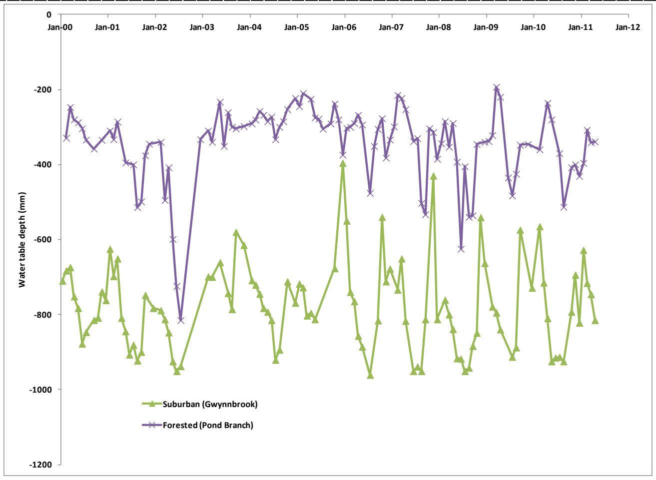
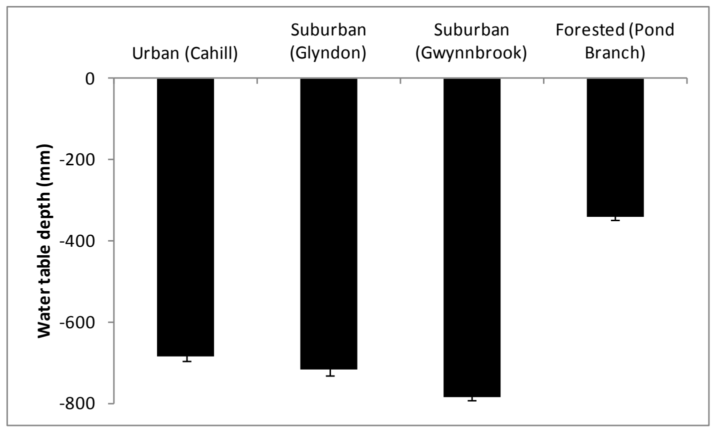


Figure 11. Water table depth in forested reference, suburban and urban riparian zones from 2000 – 2010. Wells were located 5 m from the center of the stream.





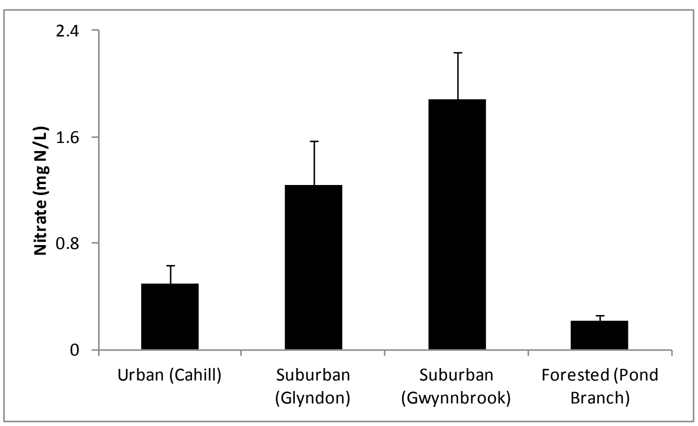
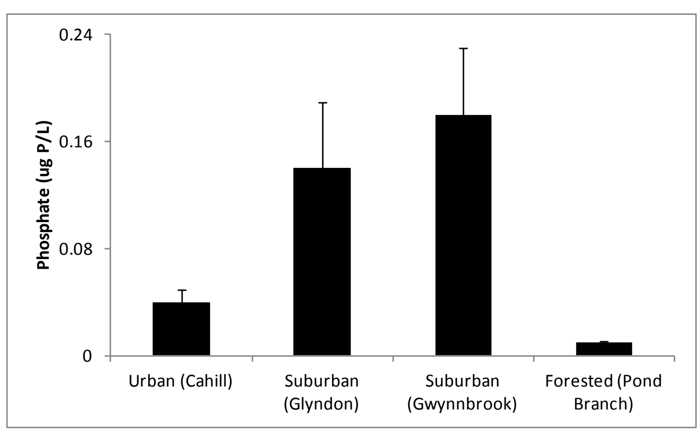


Figure 12. Mean water table depth (top), groundwater nitrate (middle) and groundwater phosphate contractions in forested reference, suburban and urban riparian zones. Values are mean (standard error) of approximately monthly measurements from 2000 – 2010. Wells were located 5 m from the center of the stream.



6. ***The Urban Watershed Continuum*.**
The examples from the LTER site indicates that engineered headwaters increase downstream subsidies of nitrate, phosphate, sulfate, carbon, and metals compared with undeveloped headwaters, and there are increased longitudinal transformations of carbon and nitrogen from suburban headwaters to more urbanized receiving waters. In addition. hydrologic connectivity along the vertical dimension between ground water and leaky pipes from Baltimore's aging infrastructure elevates stream solute concentrations. Across time, there has been increased headwater stream burial, evolving stormwater management, and long-term salinization of Baltimore's drinking water supply. Given interest in transitioning from sanitary to sustainable cities, it is necessary to recognize the evolving relationship between infrastructure and ecosystem function along the urban watershed continuum.

7. ***Influence of Organic Carbon Sources on Denitrification*.**
We find that dissolved organic carbon (DOC) and nitrate loads increased with runoff according to a power law function that varied across sites, and stream particulate organic matter (POM) was a mixture of periphyton, leaves, and grass that varied across site types. Laboratory experiments indicated that organic carbon amendments significantly increased rates of denitrification more than nitrate amendments across streamflow conditions and sites ($p < 0.05$). Denitrification experiments with naturally occurring carbon sources showed that denitrification was significantly higher with grass clippings from home lawns, and overall unrestored urban sites showed significantly higher denitrification rates than restored and forest sites ($p < 0.05$). Therefore, urbanization influences organic carbon sources and quality in streams, which can have substantial downstream impacts on ecosystem services such as denitrification. Overall, an urban watershed continuum framework proposes testable hypotheses of how transport/transformation of materials and energy vary along a continuum of engineered and natural hydrologic flowpaths in space and time.

8. ***Phosphorus Dynamics in Urban Streams*.**
We find exports of soluble reactive phosphorus (SRP) and total P (TP) increased with watershed impervious surface coverage, and were highest in a small urban watershed than in watersheds with forest and low-density residential land use. Along the Gwynns Falls, the greatest proportion of SRP (68%) and TP (75%) was contributed from the lower watershed, where urban areas were the dominant land use. Load duration curve analysis showed that increasing urbanization in watersheds was associated with shifts in P export to high-flow conditions (>2 mm d^{-1}). SRP concentrations during low-flow conditions at urban headwater sites were highest during summer and lowest during winter. Shifts in streamflow and alterations in water temperatures owing to urbanization and climate can thus influence stream water P concentrations and P export from urban watersheds.

9. ***Concentrations and Effects of Pharmaceuticals Across an Urban Land Use Gradient*.**
Although we are still running the chemistry from the passive samplers at the University of Nebraska, the passive diffuser data suggests that exposure varies along the urban gradient. The response of the biofilms across the four sites studied

suggested that for some compounds, the biofilms are resistant to some drugs, e.g. caffeine, but that some drugs have affects on the biofilms regardless of extent of urbanization. These findings will be combined with the passive sampler data to ultimately shed light on the connection between exposure and responses of the ecological community to these urban contaminants. The work of two undergraduates in Rosi-Marshall's laboratory (that will continue as honors theses this academic year) suggests that short-term exposure (on the order of only six days) can elicit strong suppression of primary production and respiration. We hope that the data from the passive samplers will provide us with insights into the compounds present in BES streams and allow us to further develop ecological research exploring these compounds and the extent of exposure needed to influence C and N cycling in BES aquatic ecosystems.

10. ***Urban Water Cycle***.

Watershed delineation

The forested reference watershed, Baisman Run, does not show significant differences across grid resolutions, while the highly urbanized DR5 watershed shows notable differences in the spatial location of watershed boundaries for each of the grid resolutions. Watershed area changes approximately 23% for DR5 from 1-m to 30-m but only 1% across the same scales for Baisman Run. The largest differences in watershed area are in the smallest watersheds or those that have major road infrastructure relative to overall area within them. For instance, DR1 and DR5 have differences in watershed area of 18% and 26%, respectively, between the 1 meter and 30 meter resolutions. These watersheds are both relatively small in area and have major multiple lane highways within them. Pond Branch, a forested reference watershed, and Glyndon, a watershed with suburban development, have differences in area of 7% and 16%. Results using the stream layer extended to include storm drains for Dead Run tributaries indicate convergence of watershed area estimates compared to the analysis that excluded storm drains. For DR5, inclusion of storm drains decreased the coefficient of variation by 94%. Drainage areas are similar for DR5, but spatial variability in the location of the watershed boundary continues to persist across scales.

The results show that *we cannot assume that an urban watershed has a known and fixed boundary or drainage network*. Pixel resolution and topographic representation become increasingly important variables when watershed areas are small and urbanization levels are high. Accurate representation of buried streams appears to improve the consistency of estimated watershed areas across grid resolutions, but these datasets can often be incomplete or difficult to obtain. Large urban structures, such as highways, and the rearranging of the landscape that accompanies these features act as a dominant control when represented topographically. This infrastructure creates barriers that behave as topographic divides, leading to inaccurate depictions of watershed and network properties. Network datasets, such as flow lengths grids, also appear to show scale dependence. Careful consideration of the implications of grid resolution on network properties as they relate to project objectives should be made when undertaking hydrologic analyses in small urban watersheds.

Hydrograph analysis, watershed statistics and width function comparisons

We generated unit hydrographs for pulse events for groups of watersheds with comparable drainage area but varying impervious cover, age of development, watershed shape, and stormwater management. The set illustrated below are for Gwynns Falls at Delight, Scotts Level, Powder Mill Run, Dead Run at Franklintown, and Maidens Choice Run, with drainage areas between 8.6 and 14.3 km^2. Maidens Choice, Dead Run and Powder Mill Run have the highest percent impervious area, highest modified drainage density and lowest percent of drainage area controlled by stormwater management, although Dead Run has strong internal variation among its tributaries particularly with respect to stormwater management (SWM), with a correspondingly higher cumulative percent area controlled by SWM. Scotts Level and Gwynns Falls at Delight have somewhat lower values of percent impervious area and modified drainage density, but Delight has significantly more stormwater management whereas Scotts Level, which was developed much earlier than the upper Gwynns Falls, has only 10.5 percent of drainage area controlled by SWM.

All of the unit hydrographs in Figure 13 are aligned so that the steep rise in discharge begins at the same time step. Relative magnitude of peaks is not a function of actual peak discharge but simply reflects the proportion of unit runoff concentrated within the time of maximum discharge. Powder Mill Run and Maidens Choice Run produce extremely rapid response hydrographs that are almost identical other than a slightly longer time of rise for Powder Mill Run, which has a drainage area about 10% smaller than Maidens Choice. Dead Run at Franklintown reaches peak discharge as rapidly as Powder Mill and Maidens Choice but has a more attenuated response which is partly attributable to the size of the watershed (about 40% larger than Powder Mill). The Delight and Scotts Level watersheds both have much more attenuated response, which is consistent with the observations above about watershed properties. Equally interesting is the fact that Delight has a larger drainage area, slightly lower impervious area, and a much greater fraction of watershed area controlled by SWM than Scotts Level, yet it has a much quicker response compared with the more attenuated pattern observed at Scotts Level. Initial inspection leaves open the question of whether or to what extent either watershed shape or SWM affects watershed response to a pulse of rainfall.

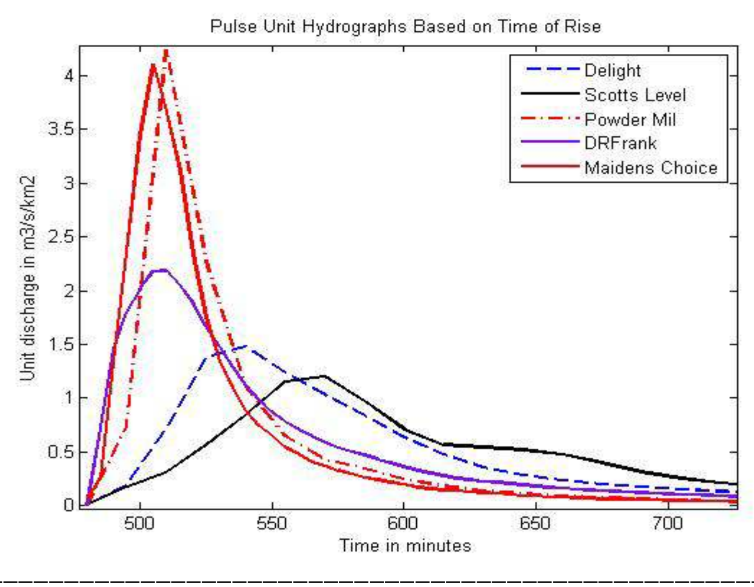


Figure 13. Pulse unit hydrographs for five watersheds with drainage areas between 8.7 and 14.3 km^2.

Figure 14 illustrates a comparison of plotted width functions, represented as frequency distributions for flow path lengths, for the same five watersheds whose pulse unit hydrographs are represented in Figure 12. We compared width functions based on the augmented drainage network with width functions based only on existing channels and found that the augmented drainage network produced a much closer representation of hydrograph shape. We compared width functions based on the augmented drainage network with width functions based only on existing channels and found that the augmented drainage network produced a much closer representation of hydrograph shape. We also found that a single value of the velocity ratio was not able to represent the comparison among these five unit hydrographs adequately. The curves appear to be reasonable first approximations of the comparative shapes of pulse response, given that only a single parameter was adjusted. However the question of whether the different values chose for the velocity ratio in different watersheds are physically meaningful remains to be investigated. No attempt was made to represent other watershed characteristics such as soil type or stormwater management, but we do have a method in preparation that may allow us to represent stormwater management features along a flowpath as filters that retard flow.

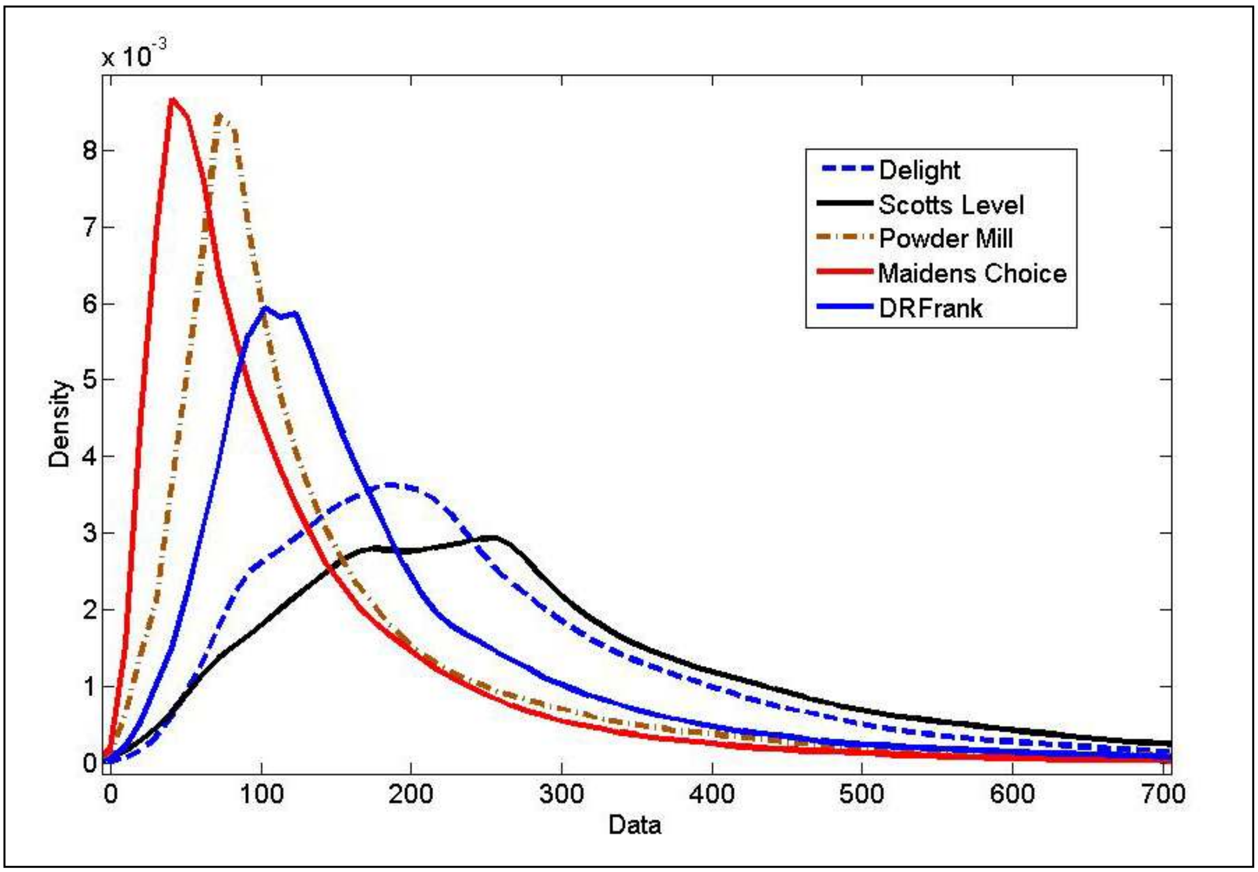
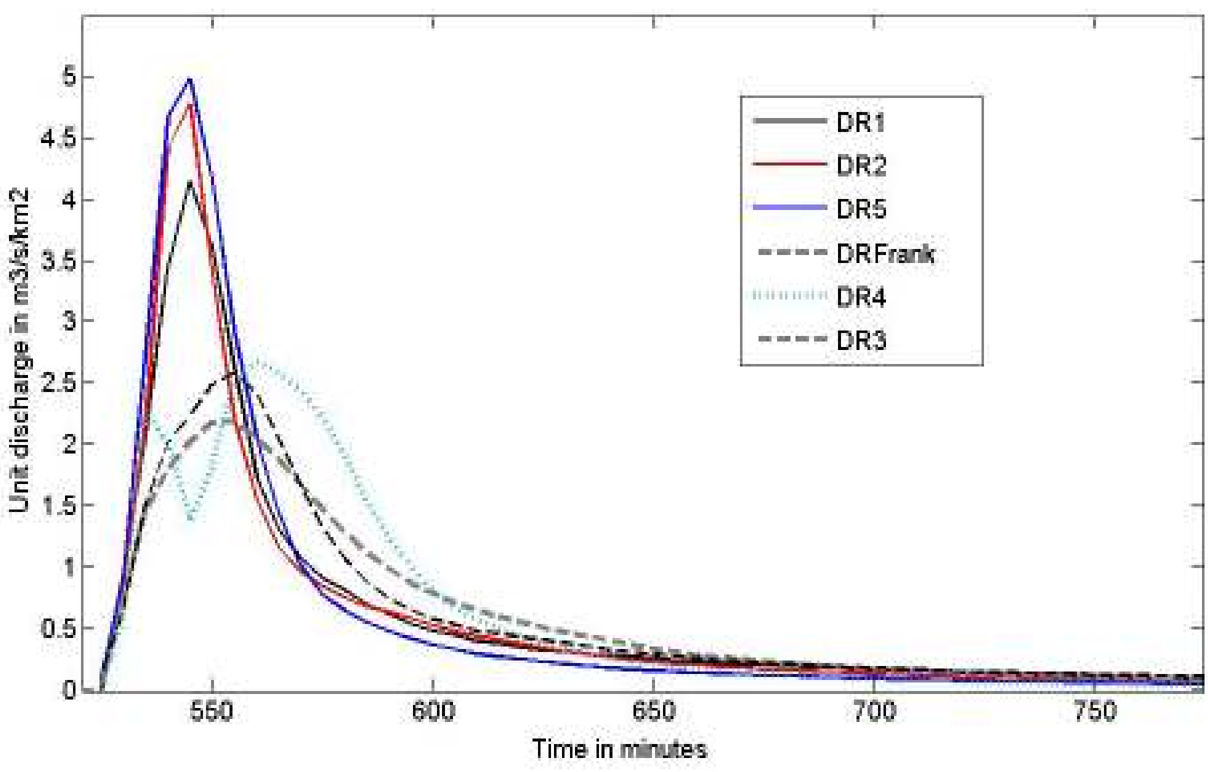
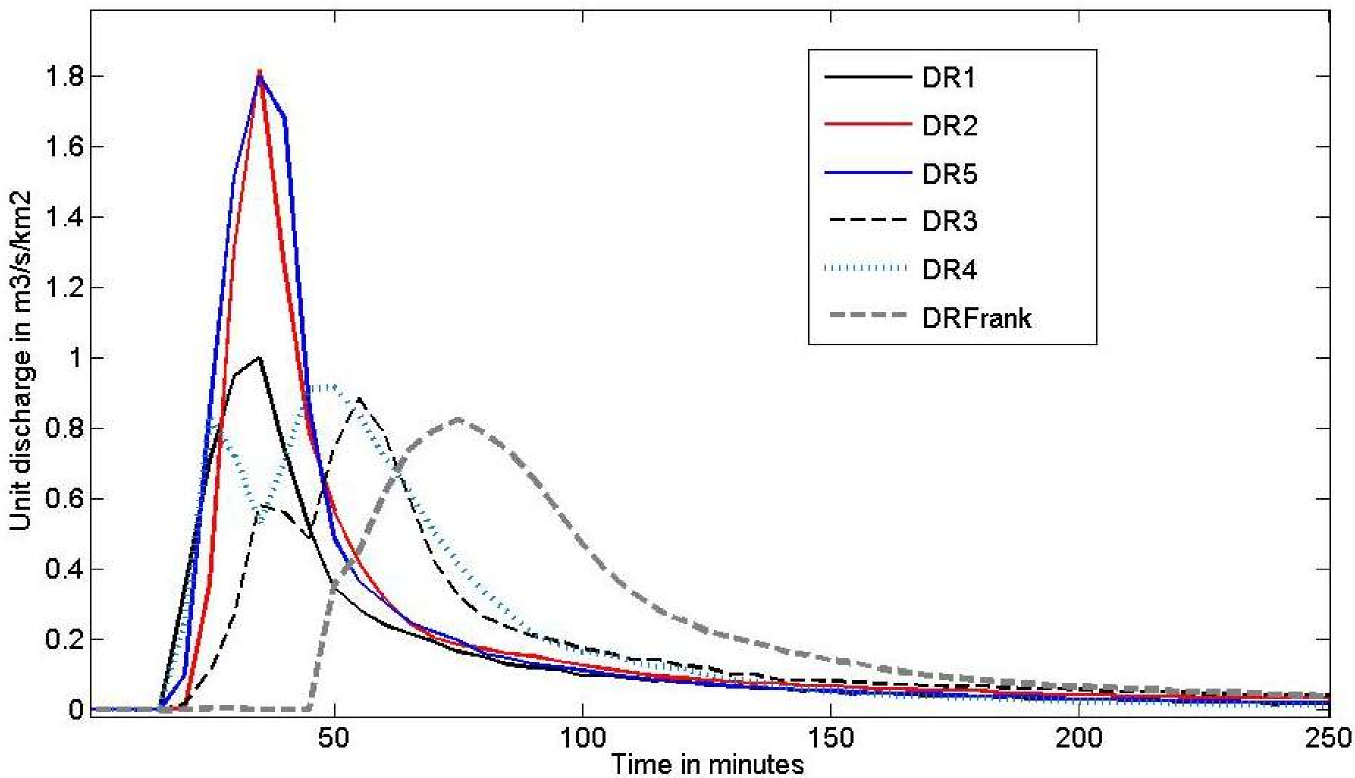


Figure 14. Frequency distributions fitted to width functions generated for the five watersheds whose unit hydrographs are represented in Figure 13.

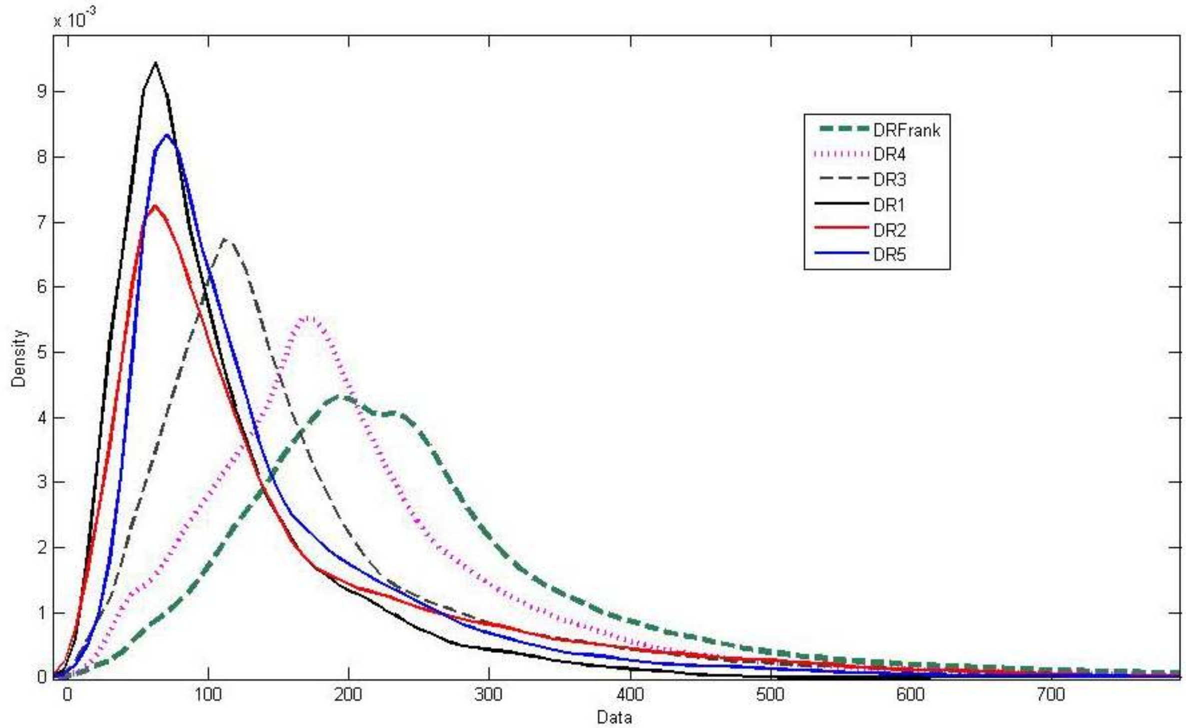
Figure 15 illustrates the comparison of pulse unit hydrographs derived for all six Dead Run gages with three scales of nesting: DR1-2-5 at scale 1-2 km^2, DR3-4 at scale 5-6 km^2, and DR Franklintown at scale 14 km^2. DR3 and DR4 together make up nearly 80% of the total drainage area at the Franklintown gage. In comparing the three headwater tributaries there is little evidence that differences in percent impervious area, drainage density or stormwater management exert a dominant influence on runoff response. Stormwater management controls more than 30 percent of the DR2 watershed and almost half of the DR1 watershed but is virtually absent from the DR5 watershed, yet the three watersheds exhibit almost identical storm response. The pattern of downstream attenuation from the headwaters to DR3 and DR4 is evident but the relative timing of the hydrographs is not shown because all six were started at the same time step corresponding to the beginning of the steep increase in the rising limb. It is evident that DR4 displays a double peak, with its rising limb as steep as the three headwater tributaries and with the initial peak preceding the peak at its own upstream tributary, DR5. We interpret this as a result of the influence of local storm drains from the large impervious area close to the DR4 gage contributing an early runoff pulse prior to arrival of the "main" runoff signal from the rest of the watershed. The relative timing and magnitude of these two pulses varies from storm to storm depending on the short-term spatial and temporal pattern of precipitation within the watershed.





In order to illustrate the relative timing of watershed response to a pulse rainfall event, we selected the storm of June 27, 2008, which had a virtually uniform spatial and temporal distribution of rainfall over the Dead Run watershed with almost all of the rainfall concentrated in less than 30 minutes. Storm period rainfall was approximately 10 mm. The hydrographs shown in Figure 16 demonstrate the double-peak phenomenon for both DR3 and DR4; DR4 peaks 10 minutes before DR3 even though drainage area at DR3 is about 20% larger. The Franklintown hydrograph shows only modest attenuation compared to the DR3 and DR4 tributaries but its peak lags behind DR3 by 20 minutes and the beginning of the steep rise at Franklintown lags all of the tributary watersheds by 30 minutes.

Frequency distributions fitted to the width functions for Dead Run at Franklintown and all five gaged tributaries are illustrated in Figure 17, using a channel:hillslope velocity ratio of 100:1 for all six watersheds. The relative shapes and positions of the DR1, 2, and 5 width functions and the Franklintown width function are quite similar to the patterns displayed in the relative shape and timing of the hydrographs for the pulse event of June 27, 2008. The relative positions of the DR3 and DR4 are reversed, presumably because DR4 is the larger watershed and the width function as expressed here makes no provision for differences in average velocity between watersheds.



The width functions also fail to capture the double-peak phenomenon. Because we attribute the double peak to the influence of local storm drains, it was our expectation that coupling local impervious areas to the drainage network would capture this effect. Design criteria for storm pipes draining large parking areas typically include extremely high velocities and it is possible that a simple adjustment of the assumed constant velocity for the large local storm drains might allow us to account for the observed phenomenon. The Franklintown width function has a more gradual slope than the actual rising limb of the Franklintown hydrograph, indicating that the delayed pulse response is more abrupt than our representation of the drainage network topology would predict. Nevertheless these patterns suggest that the width function approach may have some utility in characterizing nested watershed response across scales and merits further attention.

Wetness Index

Preliminary examination of spatial patterns of the topographic wetness index, generated using the algorithms cited earlier, supports the observation by Tenenbaum et al. (2006) that urban development profoundly alters surface flowpaths and local potential for runoff generation associated with convergent topography. Figure 18A illustrates the spatial pattern of the wetness index derived from the NED 1/3 arc-second topographic data. The 1/3 arc-second data do not preserve the topographic footprint of urban infrastructure and reveal the underling structure of the landscape. The location shown in the images is exactly the same as the location shown in Figure 14. Figure 18B shows the spatial pattern of the wetness index derived from the 5-m LiDAR-based DEM for the same location.

In figure 18A the major convergent flowpaths in the landscape are clearly visible and the pattern of contributing areas that might develop with increasing saturation is easy to see and is concentrated along the riparian zones and extending upstream along the tributaries. In this particular watershed, the Red Run watershed, county regulations prohibit development in the riparian zone, percent impervious area is lower than in watersheds like Dead Run and Powder Mill Run, and valley bottoms maintain at least some of their hydrologic and ecological function. However even in this watershed, identified by Baltimore County government as a success story for environmental management in a growth corridor, it is evident that the spatial distribution of flow paths has been disrupted and areas with high values of the wetness index are less prevalent and occupy much smaller, often discontinuous patches. Riparian zones are still visible but the pattern of topographically-driven flow paths outside of the main valley floor appears much more chaotic. D'Odorico and Rigon (2003) show how maps of the wetness index can be used to predict variation of flowpath lengths that are triggered with increasing saturation of the watershed, in turn altering the probability distribution of travel times and the cumulative watershed response to a precipitation event. Continuing work will seek to assess the extent to which the spatial pattern of the wetness index as modified by urban development can help us to explain patterns of watershed response with changing conditions.

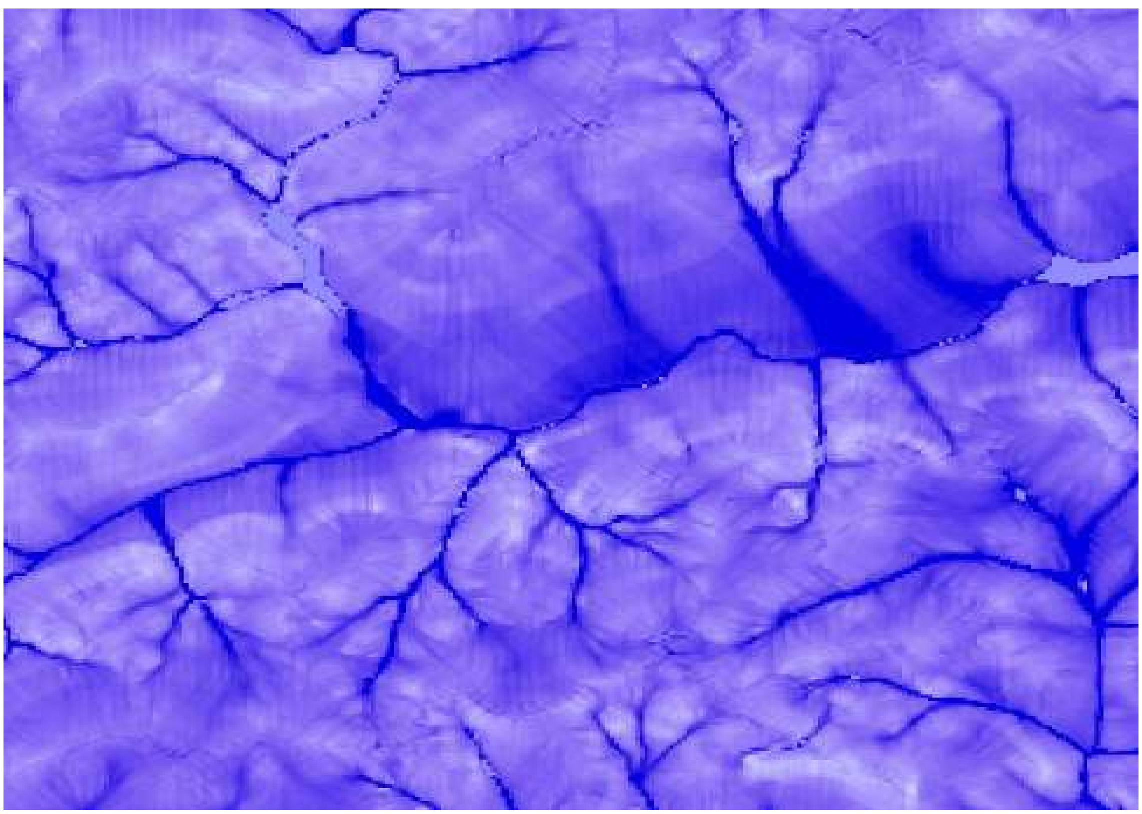


Figure 18A. Spatial pattern of the topographic wetness index derived for the location in the Red Run watershed show in Figure 5 using the 1/3 arc-second National Elevation Dataset (approximately 9-m horizontal resolution.)

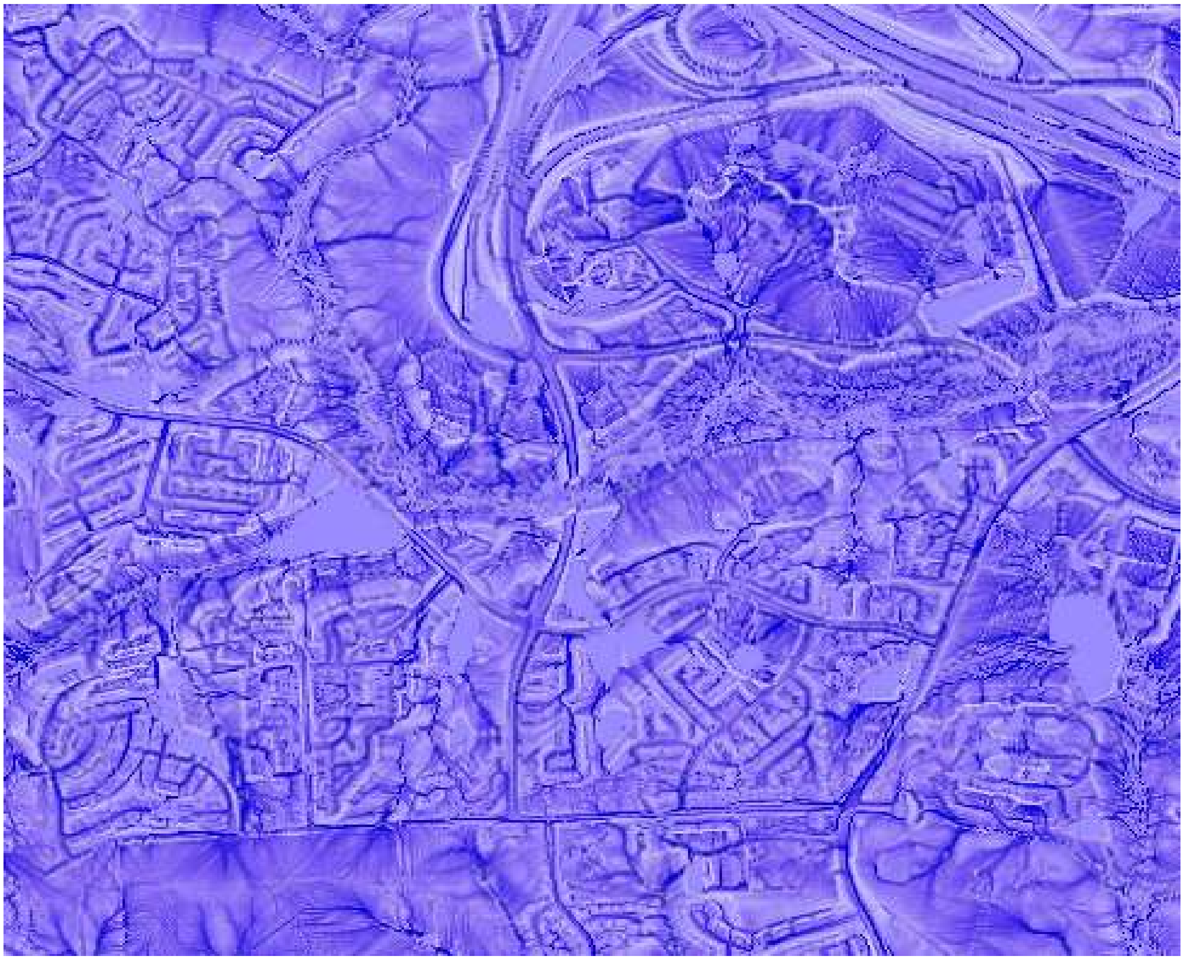
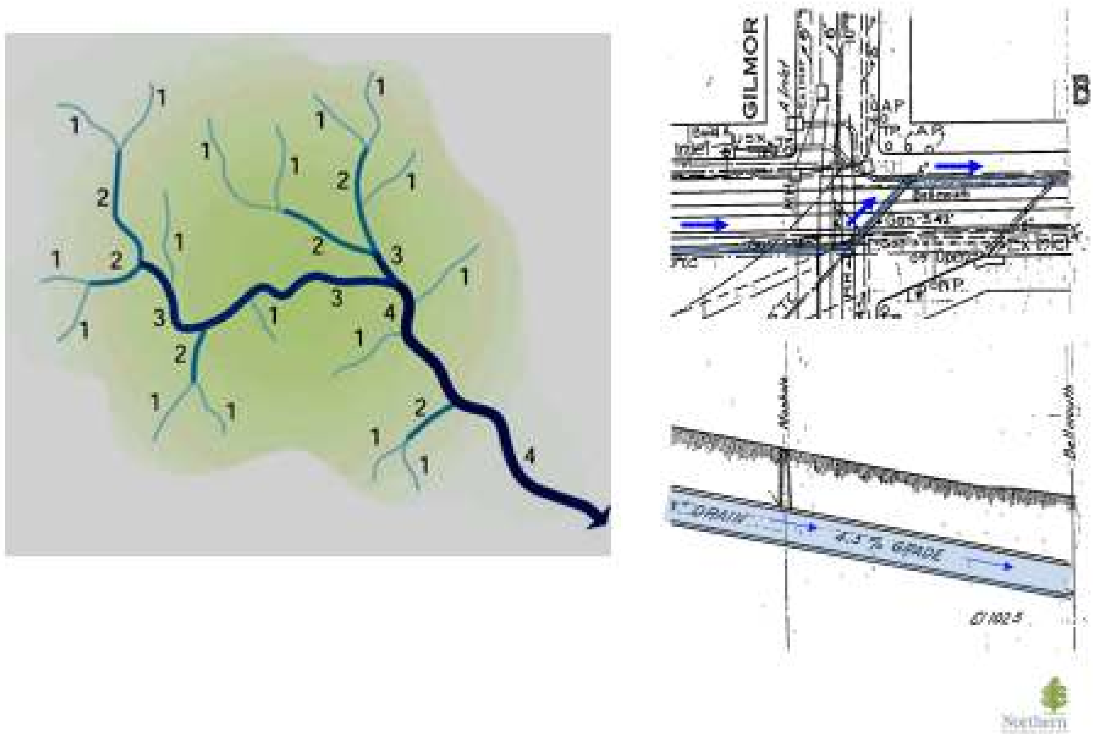


Figure 18B. Spatial pattern of the topographic wetness index derived for the same location, derived from a 5-m resolution LiDAR-based DEM.

11. ***Watershed 263 a New Stormwater Management Paradigm***.

Data revealed several potentially important implications for watershed restoration efforts. First, the underground, or "buried stream" baseflow loads can be substantial, even relative to the surface urban runoff loads in highly impervious urban catchments. Second, the large pollutant load exports from these residential catchments suggest that older, highly urban landscapes may be important hotspots, as these small headwater catchments are numerous in the urban landscape. Third, the complex nature of the pollutant export patterns at Baltimore and Lanvale, both spatially and temporally, suggest that there may be complex drivers involved. Since this complexity may involve one or more systems of urban water networks, conceptualization in terms of the Urban Watershed Continuum (Kaushal and Belt, 2012) may be a useful tool to use both in their characterization and in designing interventions. Lastly, if these small headwater catchments truly represent a larger typology in terms of being hotspots, the characterization and mapping of older ultra-urban catchments may well be worthwhile given the large numbers of potential analogues in the urban landscape and the likely increasing role of aging infrastructure in creating more and larger “unseen” pollutant loads.

Storm Drainage Networks: Natural & Unnatural



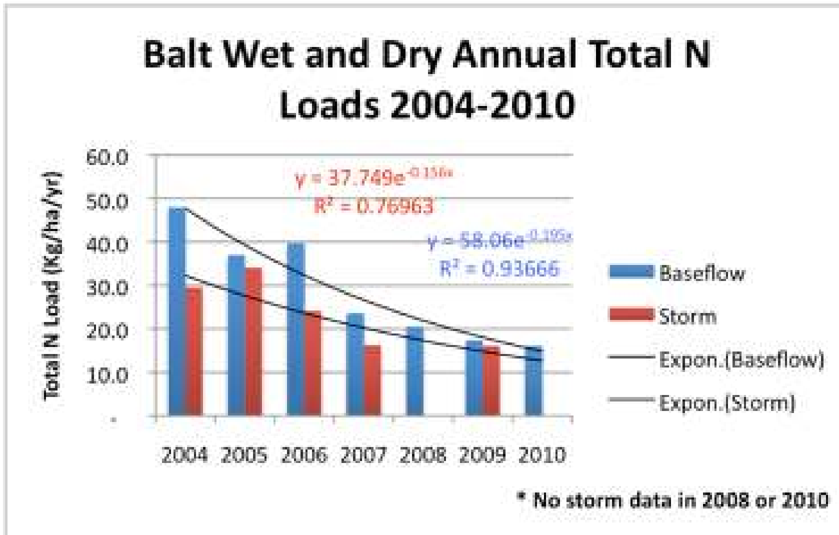
Watershed 263: Ultra Urban, with Groundwater Matrix Issues?

Lanv Baseflow

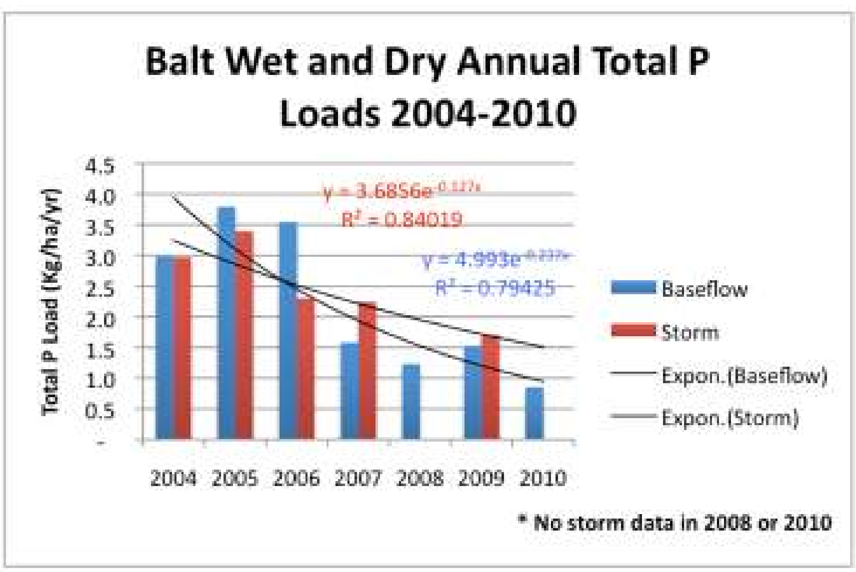
Balt Baseflow

Baltimore City DPW Photos

Nitrogen Baseflow and Stormflow Loads: …Decreasing Over Time



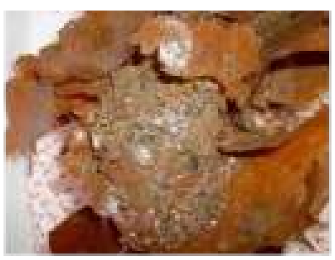
Phosphorus Baseflow and Stormflow Loads: … Also decreasing Over Time



12. ***Organic Matter in Urban Streams***.
We found that litter breakdown rates, as determined by the negative exponential decay model, were highly dependent on the length of the experiment and when runoff events occurred in the suburban stream. At 69/71 days, k values were similar in the forest and suburban streams. At 96 days the forest stream k had not changed much, but at the suburban stream (98 days) k had increased by 164% because of several moderate storms (ca. 5 cm rainfall) that had occurred within the last 7 days of the experiment. Since runoff events of this size had occurred earlier in the process without changes in breakdown rates, the importance of the cadence of runoff and abrasion based losses in suburban streams was underscored. This also speaks to the need to incorporate of discharge or at least precipitation data into urban leaf litter breakdown studies as important ancillary data, or perhaps as covariates in a mass loss model that addresses temporally complex breakdown processes (i.e., non-linear).

Leaf characteristics for London Planetree (LP) and American Sycamore (Syc) leaves were statistically significant ($\alpha=0.05$). Leaf leaching rates, brittleness and moisture content differed significantly between the two leaf species. Leaves of the urban tree *P. acerifolia* were 33% more brittle and held 6.4% less moisture than *P. Occidentalis*. Moreover, in-stream losses showed that by10/12 days, the London Planetree leaves lost twice as much mass (13.2%) as the American Sycamore leaves (6.7%), primarily due to leaching. There also seemed to be an “urban” location effect, as the Planetree leaves from the urban source sites lost 36% more in the leaching process than leaves from the suburban source site.

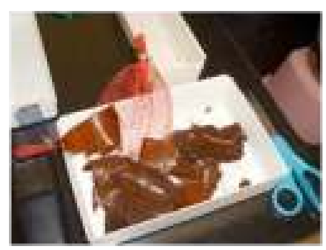
The breakdown rates among the four riparian sites for Sycamore leaves in the forest and suburban streams over 69/71 days, and for the forest stream at 96



Sediment in Leaf Bag 328 (forested catchment; Gutter, Urban Litter)

Skeletonization (& Tipulid) , Bag 249 (forested catchment; Landscape, Urban Litter)

Bag 289



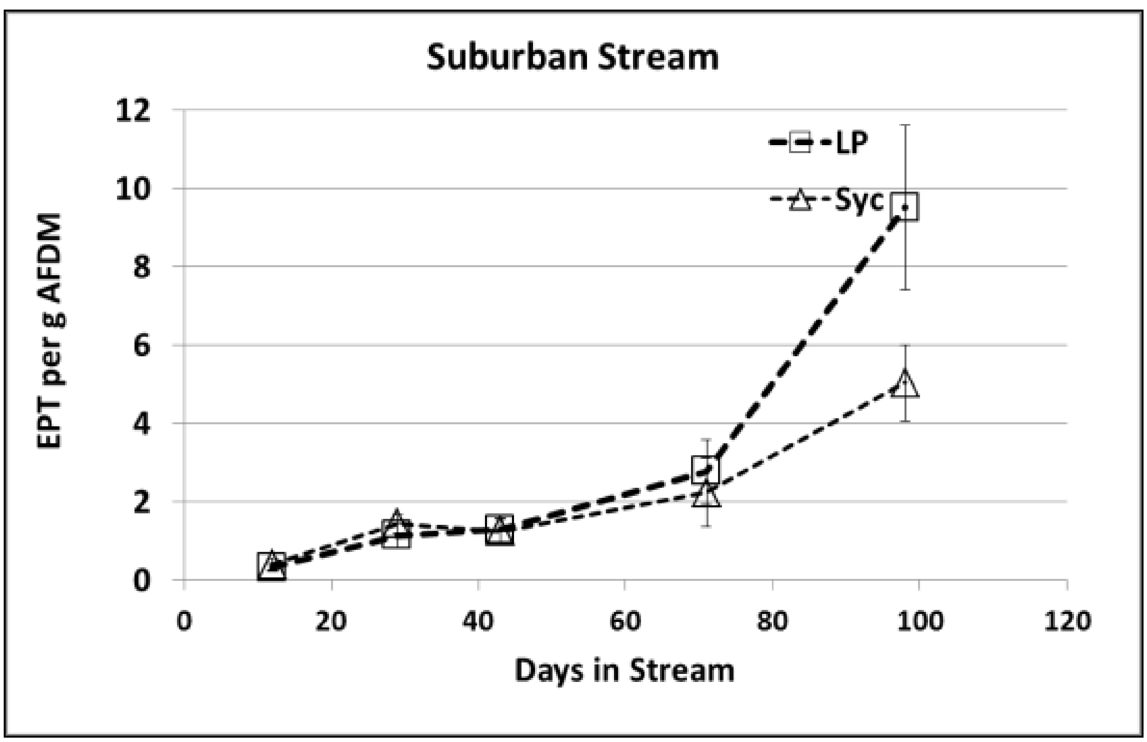
Bag 289 (forested Catchment; Gutter, Suburban Litter)

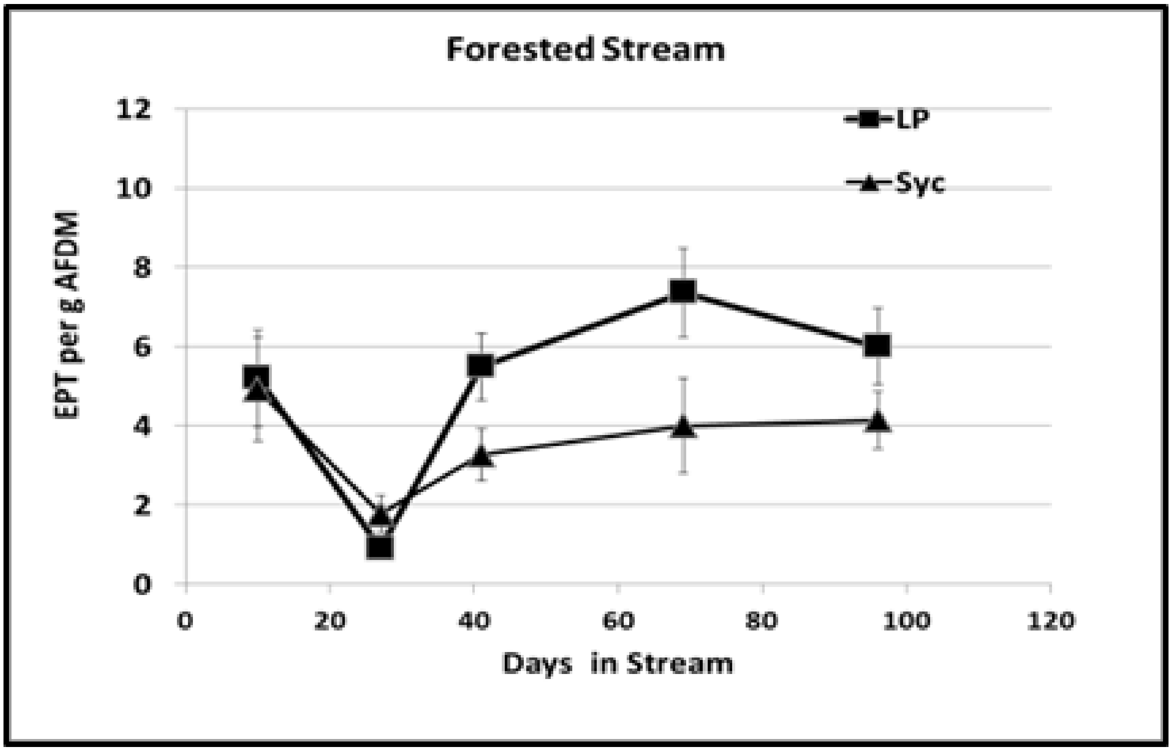
Bag 300 (Suburb Catchment; Gutter, Urban Litter)

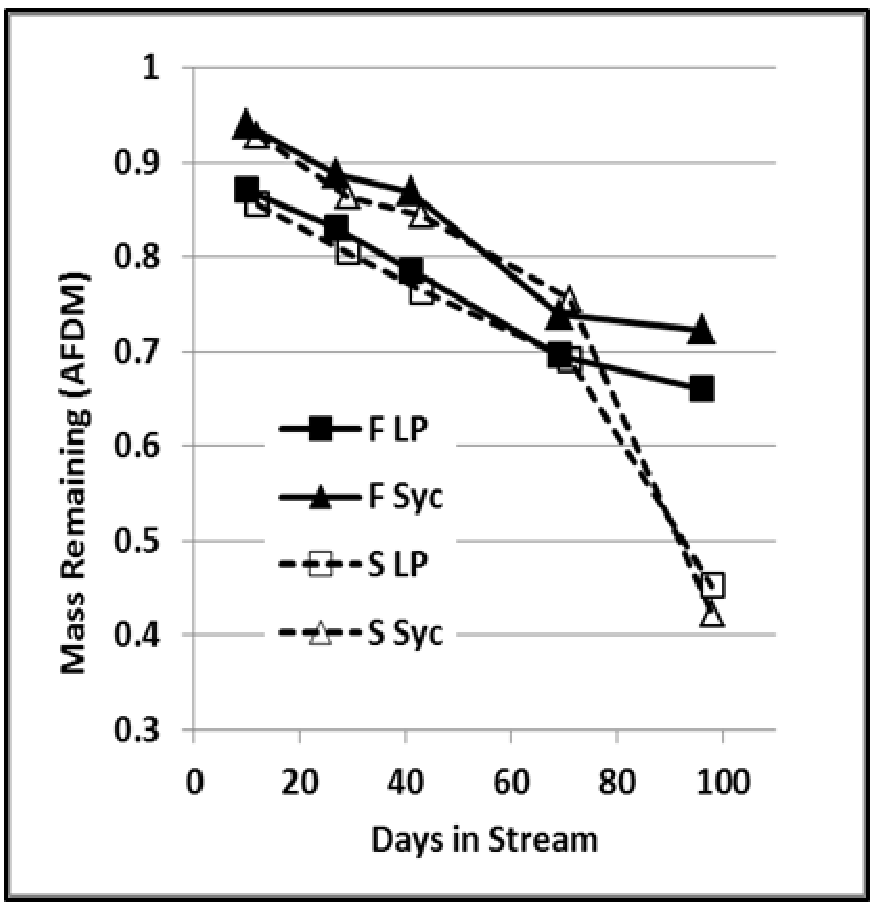
days, were similar, and ranged from -0.00220 to -0.00496. There was a tendency, for the rural site sources to have steeper slopes in the forest stream at 69 days; however, for the forest stream at 96 days and the suburban stream at 71 days, the suburban-urban sites had steeper slopes, suggesting an urban-rural based difference in breakdown rates.

There was a strongly suggestive general tendency for the macroinvertebrates to colonize the LP rather than the Sycamore leaves, especially in the forest stream. That there was much variance in the ratio temporally, but with the three groups generally showing the same changes over time suggests that this preference had a broad based mechanism that exerted an effect on diverse taxa. In the forest stream, LP bag densities were greater than Syc by 26.2%, 41.5%, 31.7% for Shredders, EPT and TMac. Similarly in the suburban stream, the LP litterbag densities were greater by 30.1%, 51.3%, and 22.7%, respectively.

These litter processing and macroinvertebrate results suggest that urban foresters, water resources engineers, and ecologists can contribute the management of urban landscapes to address leaf litter effects on urban streams in ways that not only fully recognize the complexities of the urban stream systems, but to fully integrate the "green" and "grey" hydrological infrastructure to address meaningful solutions in a world where sustainability and greening of urban landscapes may bring wholesale changes to the urban landscape-stream linkage.



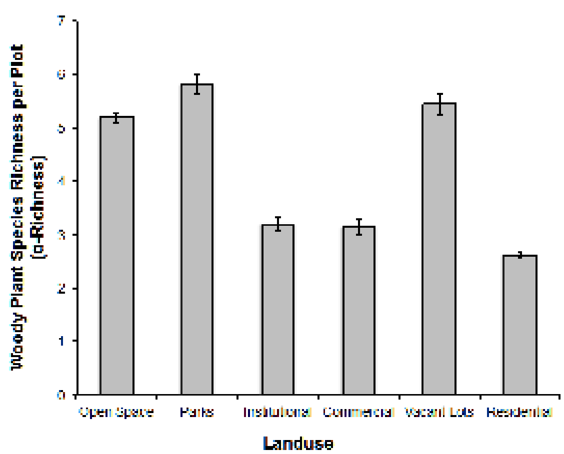

Forested Stream
EPT per g AFDM
Days in Stream
LP
Syc
0
2
4
6
8
10
12
0
20
40
60
80
100
120

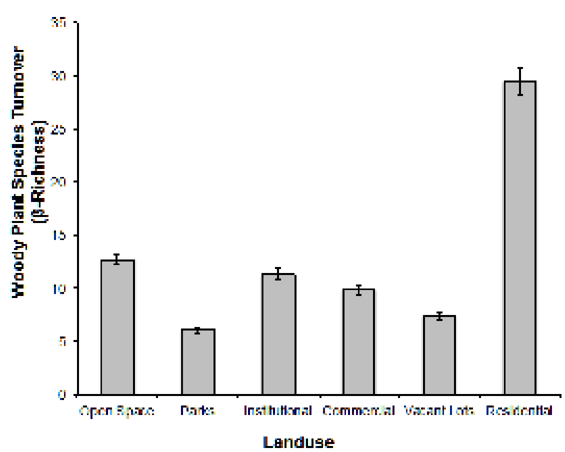

Mass Remaining (AFDM)
Days in Stream
F LP
F Syc
S LP
S Syc
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
20
40
60
80
100

Findings: Urban Metacommunity

1. ***Relationship of Trees and Soils to Nitrogen Cycling.***
All trees are identified, counted and measured (dbh) and associated soil samples collected in a series of randomly located plots. Sixty three 100 m^2 plots were sampled during the summer of 2012, bringing a total of 107 plots in the study area. A total of 23 tree species were identified. All of the data are logged into Excel files and transferred to a map of the area in ArcView. One hundred and eleven soil samples were collected. Each soil sample is tied to a specific tree on a specific substrate. There are three geologic substrates in the watershed—one dry that is predominantly a schist, another mesic that is predominately gneiss/granite, and a third which is the floodplain alluvium.

2. ***Urban Tree Metacommunities.***
A detailed analysis of 209 woody plant communities in Baltimore, Maryland that include not just remnant and disturbed habitat but also those located on residential lots, commercial lots, parks and vacant lots, revealed significant variation in local diversity. More interestingly, these communities exhibited high variation in species turnover (i.e., beta diversity) among land use types. High rates of species turnover can be attributed to many ecological mechanisms, such as differential dispersal, environmental gradients, and local interspecific interactions. However, in the built environment, the high variation observed here among landuse types suggests human preference for species composition over richness. If maintaining biodiversity in the built environment is to be a goal in conservation and sustainability plans, then incorporating the human dimension into the mechanisms that both maintain diversity locally and generate it between habitats will be necessary to understand.





3. ***Assembly of Urban Pond Metacommunities.***
Our hypotheses were supported overall. Dispersal increased diversity significantly, and the presence of chloride significantly reduced diversity. The interaction between these two factors was highly significant. Biodiversity levels were highest when dispersal was allowed and no chloride was present, but lowest when dispersal was inhibited under the same no chloride treatment. This suggests dispersal played a strong role in shaping local diversity patterns. Interestingly, the source of colonists interacted strongly with the dispersal treatment, but opposite to the pattern we predicted. Dispersal increased diversity of the urban source pool beyond the rural effect. We contend that this could be due to a "rescue effect" for some taxa in the urban pool of colonists. Why this should be more important for the urban regional species pool more so than the rural will require more investigation. How biodiversity is generated and maintained in the urban environment is understudied, yet important to understand from both local and regional perspectives**.** This study provides one of the first experimental tests of local versus regional factors shaping urban metacommunities.

4. ***Human Management Explains Urban Metacommunity Properties.***
We show significant differences in the spatial partitioning of diversity between “low” and “medium” management categories. “Low” management patches showed high local diversity but low turnover between local communities. In contrast, “medium” management patches showed significantly lower local diversity than the “low” management patches, but higher turnover between patches, despite the fact that both patch-types shared a common regional species pool. There was no relationship found between geographic distance between sites and site compositional similarity, which we suggest may result from mass effects caused by high levels of dispersal between sites. We suggest alternative hypotheses to explain these patterns of diversity, and present the results of preliminary experimental work to test the potential processes that shape community assembly in this system. We contend that urban ecosystems are an excellent study system for applying and extending basic ecological theory, and that a process-based and spatially-explicit approach to explaining patterns of diversity is essential to better understand the role of humans in shaping urban ecosystems.

5. ***Urban Mosquito Monitoring – Ovitraps.***
Over twelve species of mosquitoes were found, with distinct spatial and temporal patterns evident. While species richness supports an intermediate disturbance hypothesis, diversity indices (i.e., Shannon-Weiner) do decline at sites with higher impervious surface cover. Traps in the most urban settings (i.e., Watershed 263) supported a predominant invasive species community of mosquitoes, while the composition from the rural reference sites included both these same invasives and native (often non-human biting) species.

6. ***Monitoring an Invasive Mosquito Species and Community Education.***
We will complete the first season of comprehensive sampling in Baltimore in September, 2012. To date, we have conducted 47 resident surveys across our six focal city blocks and sampled 103 water holding containers. In our first sampling period (June), 82% of samples from our lower socio-economic status neighborhood

contained mosquito larvae as compared to only 28% of samples from our higher socio-economic status neighborhood. In late July, this percentage fell to 66% in Franklin Square but rose to 38% in Union Square. Additionally, initial surveys of adult mosquitoes by REU Student Brian Becker, suggests higher biting populations in Union Square versus Franklin Square by late July. These results both support our initial expectations that the abundant garbage and refuse present in our lower socio-economic status neighborhood is an important habitat for mosquito breeding. However, our results also suggest an important role for larger, more permanent breeding habitats associated with larger biting adult populations by mid-summer. Many of the garbage containers (e.g., cups, tires) that were active larval habitat in June were dry by late July. However, gardens and yard care were more likely to maintain larval habitat (e.g., planters, yard furniture/ornaments) during the hottest part of the summer. KAP survey results also showed differences in understanding of mosquito ecology across socio-economic boundaries. The most stark comparison was in response to breeding habitat. In Franklin Square, 71% of respondents didn't know where mosquitoes breed and 26% of those identified trees as the source of their mosquito problems. In the higher socio-economic neighborhood, 66% knew that mosquitoes needed standing water to breed and nobody blamed trees.
This preliminary work was used to secure a second grant, currently in the final approval process at NSF. S.L. LaDeau, P. Leisnham, D. Biehler, R. Jordan, and S. Wilson. CNH: Urban Disamenities and Pests: Coupled Dynamics of Urban Mosquito Ecology and Human Systems Across Socioeconomically Diverse Communities. NSF Coupled Natural Human Systems (CNH 1211797). $1,434,906. Start Date: Fall 2012 (to be determined).

7. ***BES Bird Monitoring Project***.

We completed the first winter bird count conducted in February and March 2012. Despite increasing evidence that urban areas support a wide variety of species, they continue to be perceived as concrete jungles of limited conservation value, and little is known about the global patterns and drivers of urban diversity. The results of the NCEAS synthesis of bird and plant data show some unique findings. Here we show, using the largest global database to date of 149 cities, that urban areas house a large proportion of the world's plant and especially bird diversity. Of the world's total known species, ca. 20% of birds and 5% of vascular plants occur in urban areas, which represent conservative global estimates. Contrary to homogenization concerns, urban areas tend to contain unique assemblages of species. The majority of urban bird species are native whereas a smaller proportion of plant species are (94% and 70% on average, respectively). Only a small number of plants and animals display cosmopolitan distributions, the most common bird being *Columba livia* (rock pigeon) and plant *Poa annua* (annual meadow grass), found in 94% and 96% of urban areas, respectively. Species richness of cities is not only correlated with climate and topography, but also with human population size, city age and urban land cover characteristics, indicating that urban anthropogenic history can play a role in defining urban diversity patterns. A manuscript has been submitted to *PNAS* from this work:

Findings: Education

Education Research: Investigations in Ecology Teaching

We have discovered that some middle school students as well as a few high school students have moderate levels of environmental science literacy, while most hold only rudimentary levels. Teachers tend to be a bit more sophisticated in their understanding but the majority still don't demonstrate the highest level of understanding as measured by our assessments. Student and teacher literacy can be improved with hands-on activities that foster active learning and critical building of knowledge upon the base that learners start with.

Contributions

1. ***Within the Principal Disciplines of the Project.***

- Contributions to research in hydrology and ecosystems include development of new field, analytical and modeling methods for investigation of coupled water, nutrient and carbon cycling in forest through urbanized catchments, including interactions between the natural and built environment, and high performance computing (HPC). New theory on the interactions of catchment scale to small scale riparian geomorphology on the patterns and processes of nitrogen cycling are being developed, with the ability to apply the theories through advanced spatially explicit ecohydrologic modeling and analysis.
- Environmental Justice: a long term perspective. Contributions to social sciences: To our knowledge, this is the first study to examine distributive environmental justice over a very long time period (60 years). This long time span allows environmental justice researchers to examine the dynamics of change, persistence, path dependency, and legacies that would otherwise be difficult if not impossible to observe. A site-specific historical approach provides insight into the dynamics of distributive justice, which is a critical starting point for subsequent process justice inquiries.
- Relationship of Trees and Soils to Nitrogen Cycling: The project is demonstrating a tight relationship between the majority of tree species and geology/soils. A half century since the area was cleared for agriculture, patterns of afforestation show different groups or associations of trees occupying different substrates, because the fundamental control which is a geologic template precedes both climate and anthropogenic disturbance. This is leading to new concepts with respect to the effects of disturbance including legacy disturbance.
- Streamflow data from BES stream gages are provided in near real-time on the USGS MD-DE-DC Water Science Center web page, and on special request to individual investigators.
- The USGS Minebank Run report provides a local example of an urban stream restoration project that was physically monitored extensively over several years and compared to document the differences in geomorphology before and after restoration.
- Methods of predicting urban influences on micro-climate. Methods of presenting information on urban temperature patterns.

- The aerial photo cover change analysis presents a new, easy and cost-effective approach to assessing cover change within cities using statistical estimates. The results indicate recent cover changes in numerous cities from across the United States and reveal that tree cover in most cities is declining.
- City tree population data present new information on the dominance of natural regeneration in cities within natural forested regions and the relative impact of tree planting on sustaining canopy cover in cities.
- This research provides new insights into the land development process and the determinants of development patterns in metropolitan regions. Up until now, researchers have largely focused on demand-side factors leading to fragmentation and sprawl, including open space amenities and the push/pull of public services. This research provides new evidence of the importance of supply-side effects on development location decisions and patterns. Because data on development costs are much harder to collect, research on the supply decisions of landowners and land developers has been much more limited. This research contributes to the nascent supply-side research on housing and land markets by generating unique spatial data on land development, costs and developer characteristics. Using these data, we are able to examine the impacts of land development regulations and uncertainty on the timing, intensity and pattern of urban development. In addition, we are beginning to understand how developers interact with each other and how spatial interactions among heterogeneous developers influences the resulting spatial pattern of land development at a parcel scale. These are questions that have not yet been considered due to a traditional lack of data particularly at the parcel scale.
- The primary contribution of our work so far is that we provide a novel and theoretically consistent approach to accounting for market conditions by deriving household bids for residential land from a structural model of utility maximization in which the optimal bid is a function of market conditions. This innovation represents a major step forward in the narrowing of the gap between non-economic agent-based models and economic-based models of spatial equilibrium. Economic theory is used to derive the optimal household and landowner bids. Agent-based modeling methods are used to model the transitional dynamics of the system. Thus our approach marries theory and methods in a way that allows for a more dynamic representation than the spatial equilibrium economic models, which rely on a conditionally dynamic approach to simulation in which dynamics are represented by a spatial equilibrium in each time period that is conditional on some source of exogenous growth (e.g., population).
- Our projects have contributed knowledge towards the effects of urbanization on stream drainage networks, the role of organic matter in urban stream ecosystems, and an investigation of future climate change on sediment fluxes of organic carbon and nutrient across land use.
- The Urban Stream Continuum work carried out has contributed toward understanding of the urban water cycle.
- The CUERE rain gage report summarizes all aspects of constructing a rain gage station and is a service to the hydrologic science community.

2. ***Contributions to Other Disciplines of Science and Engineering.***

- USGS data, reports, and online products are widely used in all disciplines of the geosciences and natural-resources management communities. USGS streamflow data specifically contributes to BES investigations of water quality, land use change, climate change, and ecosystem amenities.
- This research advances the interdisciplinary field of land change science by developing new process-based empirical models of land development that can be used to examine the influence of land use policies and spatial interactions on urbanization patterns within metropolitan regions.
- The theoretical model and the C++ code developed can be modified to integrate with physical, atmospheric and ecological simulation models on land use change and climate change.
- The Center for Urban Environmental Research and Education (CUERE) at UMBC wrote a technical report documenting all details required to construct and maintain tipping bucket raingage stations gleaned from our experience from 2008-2012. This raingage report is also a "how-to" manual provided as a service to the profession.

3. ***Contributions to Human Resource Development.***

UMBC/CUERE continues to involve undergraduate and graduate students in all aspects of its operation. This is a contribution to human resources in terms of professional development of the next generation of environmental scientists and engineers.

4. ***Contributions to Physical, Institutional, or Information Resources that Form the Infrastructure for Research and Education***

We are refining training methods in advanced spatial analysis and ecohydrologic modeling and are planning on developing on-line training material and offering short courses at ESA.

5. ***Contributions to Resources for Research and Education. Training/Development***

- University of North Carolina (UNC) researchers have provided training on advanced spatial analysis and ecohydrologic modeling to a set of graduate students, post-doctoral students and researchers at UNC and other universities. In collaboration with colleagues at University of California Santa Barbara, we have trained ~25 people on advanced analysis and modeling methods.
- In studying the relationship of trees and soils to nitrogen cycling students have been trained in tree identification, mapping, learning how to do chemical analyses of soils and studying the effects of past land use on forest associations. The REU student has also learned the laboratory techniques for chemical analyses of the soils.
- Ohio University Geography undergraduates Kim Olivito and McKenzie Spriggs transcribed environmental justice interview data collected by Co-PIs Buckley and Boone in spring 2012.
- Research conducted on forest cover change and refining the HERCULES land cover model has provided training for post-doc Dr. Weiqi Zhou. He has relocated to the Chinese Academy of Sciences in Beijing but has continued

collaborating by preparing manuscripts of work completed while a post-doc on BES.

- Post-doc Kirsten Schwarz has been mentored and trained in spatial analysis. She has also been collaborating on a multicity comparison project through an NCEAS working group. This has provided training on working with large datasets, the R statistical package and modeling. In addition, Dr. Schwarz was mentored on teaching and was engaged with structuring a course on Urban Ecology, developing course projects and provided a guest lecture.
- The ongoing USGS work with urban hydrologic networks and streamflow monitoring has contributed to the training and development of several newer hydrographers in the Baltimore office of USGS, including Eric L. Boyd, Michael C. Geissel, and Sarah J. Poole, who have been collecting the data and developing skills at interpreting streamflow records at BES stations, among others. By working at stations in urban environments, the new staff members have learned about the unstable nature of stream channels in urban watersheds and the challenges associated with collecting good data and producing high quality streamflow records in these environments.
- While working on modeling air temperature differences across the Baltimore region graduate students learned techniques of computer programming, data management, and geographic information systems.
- Two undergraduate students were mentored during their studies on metacommunities. The skills they developed included:
    - how to keep a scientific notebook
    - how to manage data
    - employ simple functions in R to summarize and visualize R
    - reprint organizational techniques
    - general approaches to experimental design, control
    - environmental sampling techniques
    - oral presentation skills
- BES Co-PI Kathy Szlavecz and her soil group hosted and mentored two high school seniors from Friends School in summer 2012. They participated in field and lab activities including earthworm and soil sampling, soil processing and data entry.
- BES Co-PIs Welty and Miller provided training in calibrating rain gages in the laboratory and maintenance of field equipment.
- Johns Hopkins University undergraduate Jason Hu participated in the riparian soil sampling project. The sampling and soil processing was part of his Independent Study for summer 2012.
- This work has contributed to the training of one graduate student in agent-based model development and computer programming using Netlogo, MatLab, and C++ code.
- This work has contributed to the training of two graduate students in GIS and spatial data analysis, econometric modeling and spatial simulation. In addition to training in research methods and interpretation, these students received training in scientific writing and presentations and in conducting interdisciplinary research. Students participated in several professional association meetings, including the Association of Environmental and Resource Economics meeting,

The North American Regional Science Council meeting, and the Agricultural and Applied Economics Association meeting.

- Tess Van Orden, a former senior thesis student, in the Department of Geology at the University of Maryland College Park has done her thesis research in Co-PI Kaushal's lab investigating controls on BOD at BES LTER site. Tess has successfully defended her thesis and enrolled as a graduate student in 2012.
- Three undergraduate students of University of Maryland, Evan Smith, Evan McMullen, Ben Wu, and one MS graduate Cassie Smith also worked in the Kaushal lab during the spring and summer of 2012. Part of their work involved in the research related to this project. They were trained in field techniques like water sampling, nutrient addition, denitrification measurement, as well as lab skills like the isotopic sample preparation, and analysis of DOC, DIC, fluorescence EEMs scans, nutrients, and major ions.
- The Bird Monitoring Project contributed to the training of two undergraduate students who worked as field assistants during the June-August counting period. Matthew Grasso will be a senior at the University of Delaware and Evan Vaeth will be a junior at Frostburg State University. Both students received training in data collection and data entry and both participated in the BES field training workshop.
- Undergraduate researcher (Derek Melzar, UMass-Amherst) has been involved in the Bird Monitoring Project. He carried out an independent study project in Spring 2012 and worked as a research assistant over the summer 2012. He compiled life history trait information on urban bird species from Phoenix and ten other cities in the United States and Mexico.
- Under the guidance of Co-PI Brian McGrath, Irene Guida, from Universita IUAV di Venezia completed her PhD dissertation entitled: *Corridors Dissolution and Genealogy of Modernity's Spatial Device*. The thesis incorporated Guida's period as a Visiting Scholar including a summer doing fieldwork in Baltimore in her analysis of the corridor in the history of architecture and urbanisms and how it has been applied to ecology as a metaphor. The dissertation also incorporates interviews with BES Co-PI McGrath and Project Director Steward T.A. Pickett.
- Also under the guidance of Brian McGrath, Sven Augusteyns, Ben Dirikx, and Esther Jacobs completed a design thesis for their Masters of Urbanism and Strategic Planning from Katholieke Universiteit Leuven, Belgium. The design thesis was situated in East Baltimore, and was presented to the Historic East Baltimore Community Action Coalition. The students completed the design work as part of the Atlantis Transatlantic Exchange Program funded by the US Department of Education and the European Union.
- Urban stream continuum work: four graduate students, three undergraduate students and one staff member acquired skills in sensor deployment, modeling, and database management resulting from NSF support.
- Heather Bechtold, Post-doctoral researcher, has been collaborating on the work on pharmaceutical compounds in BES Streams. Additionally, REU student Shelby Servais and summer intern and undergraduate honors student Arial Shogren also participated in this project.
- Two UMBC undergraduates, Hannah Leiberg and Sierra Shamer, worked on research internships for academic credit in spring 2012. Most of the work involved continuation of the hydraulic modeling work begun previously at the

Dead Run DR-5 gage and the Horsehead Branch gage. Both students learned the use of the SMS system used for creating numerical model grids from input topographic data sets and also learned how to run the TUFLOW 2-d depth-averaged numerical model in order to generate results matching surveyed high-water marks. In summer 2012, Sierra worked primarily on compiling and analyzing storm hydrographs and precipitation data, and on generating unit hydrographs for ten of our study watersheds. REU Kevin Schmidt, University of Delaware, worked as a research assistant in summer 2012. He worked on watershed geospatial analysis using ArcMap to generate augmented drainage networks and associated watershed delineations. He also used ArcMap together with Matlab to generate width functions for study watersheds across a range of pixel resolutions and channel:hillslope velocity ratios. In addition he generated wetness index maps using algorithms in the TAUDEM toolbox.

- Ph.D. student Garth Lindner, Department of Geography & Environmental Systems (GES) at UMBC, carried out many of the urban watershed cycle analyses and a helped supervise research interns. A poster on aspects of this work was presented at the Fall 2011 AGU meeting (Miller et al., 2011). Dan Jones, a MS student in GES, provided helpful ideas and technical assistance in connection with the width function analysis, which is similar to work he is engaged in on another project. Matthew Baker, Associate Professor in GES, provided technical assistance with scripts used in geospatial analysis.
- Research Experience for Teachers participant Mark Kather, from the Western School of Technology and Environmental Science in Baltimore County, worked with us in summer 2011 with support from an NSF-funded Research Experience for Teachers project at Towson University. He returned to work with us again in summer 2012, this time with support from the NASA-funded Baltimore Excellence in STEM Teaching Project at Towson University. Mark assisted with both GIS work and analysis of rainfall and runoff records for use in comparative analysis of watershed hydrologic response. He learned about urban watershed hydrology and is developing curriculum for his students based on the work done here at UMBC and will be bringing students to visit the campus and learn about our research during the academic year. He is also developing a poster for a conference presentation in September.
- Research results from BES, both that of the Cadenasso lab and other BES researchers, are used heavily in undergraduate and graduate teaching at UC Davis. Examples to illustrate fundamental ecological concepts and theory and their applications in urban ecosystems are used in Urban Ecology (PLS 162, an undergraduate lecture course) and Ecosystems and Landscapes (ECL 201; a core course in the Ecology graduate program) at UC Davis. In addition, examples are used extensively in guest lectures that Co-PI Cadenasso provides regularly to the Graduate Group in Geography and undergraduate classes in environmental horticulture, urban planning, and landscape architecture.
- Two undergraduate students participated in the Bird Monitoring Project in 2012. These students were exposed to state of the art research in urban ecology and wildlife conservation.

6. ***Contributions to Other Aspects of Public Welfare Beyond Science and Engineering.***

- Environmental justice is raised but not explicitly examined in Baltimore's sustainability plan. Given that equity and justice are foundational to sustainability, this study provides evidence to support ongoing efforts for fairer distribution of environmental burdens and benefits.
- Relationship of Trees and Soils to Nitrogen Cycling:
  - The information from this study can form the basis for a Chesapeake Bay watershed landscape model where trees are used as buffers throughout the watershed to prevent nitrogen from leaching into the soil, streams and ultimately the Bay.
  - The information from the study can provide guidance to city managers about which trees should be planted in areas that differ by geologic or soil type. This is important for Baltimore City for example which straddles both the Piedmont and Coastal Plain provinces, where geology and soils are markedly different.
- Despite recognition by the Convention on Biological Diversity of the importance of biodiversity in cities and a rich recent history of urban ecology research, a global synthetic analysis of which species inhabit urban areas is lacking. Numerous studies have examined the diversity of single taxa within cities across continents, but the majority have focused on patterns within individual cities. To facilitate global-scale comparative studies that are urgently needed, we compiled urban bird species lists for 54 cities and city-wide floras of spontaneously established vascular plants (both native and non-native species) for 110 cities. The lists encompass 36 countries on six continents and six biogeographical realms and represent the largest global compilation of urban biodiversity data to date. Our finding that bird species richness of cities is not only correlated with climate and topography, but also with human population size, city age and urban land cover characteristics, indicates that urban anthropogenic history can play a role in defining urban diversity patterns. This suggests that humans also have the potential to conserve aspects of regional diversity that can be used to promote greater biological awareness.
- Relationship of Trees and Soils to Nitrogen Cycling: This study provides new information with respect to conservation and restoration efforts. After the widespread agricultural disturbance that homogenized the landscape, recovery returns the forest cover on the landscape to a pattern controlled by geology/soils. Recovery from a singular widespread disturbance may have quite local trajectories. Thus one model for conservation/restoration is not likely to fit all situations.
- The aerial sampling approach to assessing urban cover change and city tree population data as well as the results are useful to many disciplines related to urban planning, design and management.
- The contributions made by metacommunity studies were mainly within the principal discipline of ecology, but since biodiversity is a component of sustainability plans and sustainability is a core theme in BES III, new findings lay the foundation for translating the mechanisms by which biodiversity are maintained in the built environment. As such, once we began to interact with policy makers, this work became relevant beyond science and engineering.

Publications and Products

Journal Publications

Bain, D.J., M.B. Green, J.L. Campbell, J.F. Chamblee, S. Chaoka, J.M. Fraterrigo, S.S. Kaushal, S.L. Martin, T.E. Jordan, A.J. Parolari, W.V. Sobczak, D.E. Weller, W.M. Wollheim, E.R. Boose, J.M. Duncan, G.M. Gettel, B.R. Hall, P. Kumar, J.R. Thompson, J.M. Vose, E.M. Elliott, D.S. Leigh. 2012. Legacy effects in material flux: structural catchment changes predate long-term studies. BioScience. 62(6):575-584. doi:10.1525/bio.2012.62.6.8.

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Magazine

Lee, D.N. 2012. Black & green, the new integration – 5 names in urban ecology you should know. The Urban Scientist. Scientific American New York.

Newsletter

Parks & People Foundation. 2012. Tiger mosquito study: there's a new mosquito in town. Pages 2. Watershed news: greening to improve water quality in Baltimore and the Bay. Parks & People Foundation Baltimore, MD.

Parks & People Foundation. 2012. What we have learned. Pages 3-4. Watershed news: greening to improve water quality in Baltimore and the Bay. Parks & People Foundation Baltimore, MD.

Databases

- A geodatabase of Dun & Bradstreet data was generated to analyze the distribution of facilities that were likely polluters. This geodatabase of Dun & Bradstreet facilities in Baltimore includes data for 1960, 1970, and 1980. These are point data geocoded from the addresses provided in the Dun & Bradstreet directories. Any facilities that have Standard Industrial Classification codes that designate heavy manufacturing or petrochemical facilities were included since these same criteria are used by the EPA for first screening of potential Toxics Release Inventory (TRI) facilities. Information will be shared through a publication based on a manuscript now in progress. The data will also be shared with the BES through the BES website.

- Streamflow data collected and analyzed as part of BES contributes to the USGS National Water Information System (NWIS) database. NWIS is a national database that has interactive search and retrieval options, which allows users to obtained selected data and station information on stations of interest. Typically information about USGS databases is shared through the local Center's website, during presentations or field demonstrations, or upon inquiries from other collaborative partners or the general public.

- Climate data. Daily weather data from three Baltimore area locations: 1) the BES primary weather station at McDonogh School, 2) the National Weather Service station in downtown Baltimore, and 3) the NWS station at the Baltimore Washington Airport. Since April 2000, these data are posted on the ClimDB web site sponsored originally by the LTER and the U.S. Forest Service and now by the LTER at http://climhy.lternet.edu/

- Predicted potential evaporation at the BES primary weather station at McDonogh School for years 2002 through 2006.

- Spatial modeling of residential subdivision development:
  - Baltimore County historical residential subdivision dataset: We have platted a total of 3,757 subdivisions from 1960 to 2008 in Baltimore County containing 93,667 parcel records. We have collected data on the entire internal history for all subdivisions during this period from 1960-2008. This includes the subdivision name, multiple phases of development if applicable, and land use code on each parcel. When the parcel land code is permanent open space, then we also designate the primary and secondary open space types (e.g., stormwater management, forest conservation, local open space, floodplain, wetland, etc). We have also collected the name and address for the owner and developer for each subdivision platted during 1980-2008. The plan approval data and agricultural preservation data are also in the process of being collected at this time.
  - Harford County historical residential subdivision dataset: We have platted a total of 1,784 subdivisions from 1960 to 2008 in Harford County containing 79,731 parcel records. From each historical subdivision plat file we also recorded the developer name and address which we used to generate a

developer database by linking together different subdivisions completed by the same developer. We then calculated developer characteristics such as geographic range, number of lots, number of subdivisions, and frequency of development. In addition, plan approval data and preservation data were provided by the Harford County Department of Planning and Zoning. Planning and approval data was linked to the residential subdivision history records for the years 1990 and onward including the date the subdivision plan was first submitted and the length of time until approval. Additionally parcel-level agricultural preservation data was used to construct historical records of the timing of preservation for each preserved parcel. From the data we were also able to designate the program under which the land was preserved. A large number of land characteristics were linked from the Harford County Department of Planning and Zoning and other sources. Soil quality and slope data were collected through the National Resources Conservation Service (NRCS). Forest cover, impervious surface, sewer access, zoning, school locations, and many other spatial variables were added to the data. We calculated distance to the nearby amenities, towns, and large cities. This data was also merged with the subdivision history records.

- New Datasets:
  - Soil moisture data
  - Stream synoptic data
  - Soil Temperature data
  - Soil solution chemistry
  - Examining the effects of contaminants of emerging concern in BES streams
  - New Bird Monitoring Project: Birds in Everyday Baltimore
  - Cokeysville precipitation station snow cover data
  - Land Use and Climate Change Impacts on Nutrients

Educational Products

"Biocomplexity and the Habitable Planet: Curriculum for Teaching High School Environmental Science." Alan Berkowitz and Steward Pickett from BES are part of the Principal Investigator Team developing this innovative capstone course for High School classes with collaborators from TERC in Cambridge, MA. Upon completion, Biocomplexity and the Habitable Planet will be a set of instructional materials that engages students, teachers, and their parents in the science of coupled natural human (CNH) systems. It will include two semester-long modules, each with two units, comprising student guides, teacher's guides, an ecology primer, research protocols, and data and other materials from the LTER and/or BioComplexity research communities.

Other Products

- Reference collection of seeds is being collated to be used for seed identification in sediment cores.

- Map of tree associations in the Baisman Run watershed (will be available on the BES website. (Brush)

- Video: In the Urban Ecology course taught by BES Co-PI Mary Cadenasso, a student project was to generate a short film addressing water and some other component of the urban landscape. Three films—"Water and the urban tree canopy," "Water and urban design," and "Water and human use"—are posted on You Tube and can be accessed at www.cadenassolab.weebly.com through the "teaching" tab.

- Parks & People completed an i-Tunes app for navigating the Gwynns Falls Trail working with International Mapping, Inc., Columbia, MD.

- Developed a web-based GIS map and model of Watershed 263 projects as part of an effort to better inform and educate decision-makers and citizens with regard to the project status and outcomes. This product will be further developed in the years ahead to integrate past and current BES research relating to this watershed