Water Quality Ecosystem Services in the Urban Environment

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Water Quality Ecosystem Services (WQES) in Urban Areas

- Urban/suburban Ecosystem Services
  - Goal: Assessing the actions we take to replace natural water quality ecosystem services in urban environments and quantifying the level of services (in comparison to natural landscapes)
  - Water purification: the process of removing undesirable pollutants (chemicals, materials, biologics, etc) from water (filtration, sedimentation)

Snakeden Branch (Fairfax County, Virginia) developed to 27.4 % Impervious Surface Cover
Water Quality Ecosystem Services (WQES) in Urban Areas

- Urban land use alters surface and ground water quality and hydrology
  - Increases the amount of nutrients (N, P), sediment, and other pollutants produced and transported through a watershed
- Watershed hydrologic modifications
  - Tree removal, grading, impervious cover
  - Redirection of surface water flow; increased storm runoff, volume, flow
  - Stream channel scouring/erosion
- Loss of wetlands and riparian zones that historically treated runoff

Compromises or eliminates the ability of the riparian area to provide water purification ecosystem services
Water Quality Ecosystem Services (WQES) in Urban Areas

- Stormwater that previously entered wetlands or infiltrated predevelopment may now be redirected to streams or **Best Management Practices (BMPs)**

- BMPs – the primary ACTION taken to replace water purification ecosystem services in urban environments
What are Best Management Practices (BMPs)?

- A number of land management actions designed to provide urban storm water purification before flow enters streams and downstream estuaries
  - Quality – pollutant removal (sediment and nutrients)
  - Quantity and timing – reducing velocity and flow of stormwater
- Treating and/or retaining or detaining stormwater runoff
  - above/below ground retention or infiltration, wet or dry ponds, sand/gravel filters, constructed wetlands, vegetated buffer strips, bioretention, etc.
  - public education, septic system control, pollutant disposal, etc.
Water Quality Ecosystem Services (WQ ES) Research Goal

- **Assess** the actions we take in urban areas to replace natural water purification ecosystem services (BMPs) and **quantify** the level of services (in comparison to natural landscapes)

- **Two study areas in the Chesapeake Bay watershed**
  - Fairfax County, Virginia: Soil analysis to understand soil nutrient and sediment removal and retention of commonly used BMPs in comparison with natural wetlands
  - Montgomery County, Maryland: Landscape hydrologic analysis and analysis of efficacy of stormwater treatment
Virginia Case Study

- Compare natural wetland surface soil nutrient and iron chemistries with two types of BMPs (stormwater detention basins)
  - SDB-BMPs and SDB-FCs
- How do these facilities function with respect to water purification (nutrient and sediment removal and retention) in comparison to natural wetlands?
The 2 types of BMPs (Stormwater Detention Basins)

**SDB - BMP**
- Flood control and water quality benefits (increased retention time)
- No concrete trickle ditches, wetland vegetation

**SDB - FC**
- Flood control only
- Concrete trickle ditches, usually mowed,
  Usually dry except during a storm
Virginia Case Study

- Fairfax County, Virginia
  - suburb west of Washington DC

- 12 natural wetlands (RED)
  - 1% - 29% watershed impervious surface cover in the surrounding watershed

- 6 stormwater detention basins
  - 3 SDB-BMPs (DARK BLUE)
  - 3 SDB-FCs (LIGHT BLUE)

- Collected and studied soils
Soil Phosphorus Concentrations

Oxalate-extractable P

- SDB BMP: 256.3 a
- SDB FC: 189.0 b
- NATURAL WETLAND: 194.0 b

NaOH-extractable P

- SDB BMP: 178.1 a
- SDB FC: 136.2 a, b
- NATURAL WETLAND: 135 b

Total Phosphorus

- SDB BMP: 831.9 a
- SDB FC: 652.1 b
- NATURAL WETLAND: 643.3 b
Phosphorus Sorption Isotherms

mg P / 100 cm³ soil

u mol P / L

- SDB-BMPs (n=3)
- SDB-FCs (n=3)
- natural wetlands (n=12)
Soil Phosphorus Saturation

- Saturation of available soil P binding sites allows indication of potential for P desorption
- SDB-BMPs ~8.1%
- Natural Wetlands ~8%
- SDB-FC ~7.4%
- P release and export increases with saturation level (20-32%)
Sediment Deposition – Using Iron Chemistries

Crystalline and Total Fe

- Crystalline Fe
- Total Fe

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crystalline Fe</th>
<th>Total Fe</th>
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<tbody>
<tr>
<td>SDB - BMP (n=3)</td>
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<tr>
<td>SDB - FC (n=3)</td>
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<tr>
<td>Natural Wetland low %ISC (n=4)</td>
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<td>Natural Wetland moderate %ISC (n=3)</td>
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<td>Natural Wetland high %ISC (n=5)</td>
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- a
- b
- x
- y

USGS
Virginia Case Study Findings

- SDB-BMPs more similar to natural wetlands
  - Significantly higher P concentrations
  - Soil P sorption capacities similar to natural wetlands
  - Fe suggest enhanced sediment deposition

Specific BMP designs may help better provide important ecosystem services including flood mitigation, prevention of stream degradation, replacement of water purification ecosystem services
Maryland Case Study

- Different BMPs work differently…..
- Watershed land use, soils, topography, spatial configuration, use in series, etc, etc
- Working with a team to consider management practices in a landscape level analysis
- Method:
  - Create detailed geographic databases, collect environmental monitoring data, interpret the use of BMPs at a watershed scale using local level detail
  - Goal: identification of a suite of watershed anthropogenic indicators important for water purification in urban watersheds

How does the presence, type, and spatial pattern (management protocol) of stormwater BMPs in a suburban watershed affect the provision of water purification ecosystem services?
Maryland Case Study
Clarksburg Special Protection Area (CSPA)

- 5 study sites (sub watersheds)
  - 0.9 – 3.4 km²
- Forested watershed on parkland
- Previously built out control using pre-2000 design criteria
- 3 developing test areas
- 5 continuous-record USGS stream gages
- 2 precipitation gages
Maryland Case Study
Clarksburg Special Protection Area (CSPA)

- Developing under SPA (Special Protection Area) guidelines
- Designed to protect high quality streams in developing areas
  - Protecting natural features, promoting groundwater recharge, innovative and redundant stormwater management structures

- BMPs
  - Virtually all stormwater is treated
    - Often redundant
  - Advanced sediment and erosion controls
  - Stormwater BMPs in series
    - Small drainage areas
    - Interception of water further upstream
Maryland Case Study

Data Collected / Analyses Done

- **BMP mapping**
  - Sediment control during development
  - Stormwater management after development

- **Stream Monitoring**
  - Stream flow (USGS gages)
  - County: rapid habitat assessment, geomorphology, water temperature, sediment, and benthic macroinvertebrates

- **Precipitation**
Maryland Case Study
Data Collected / Analyses Done

- LiDAR (Light Detection and Ranging) - airborne remote sensing
Maryland Case Study Preliminary Findings

- Clarksburg: *sediment control BMPs (development) did not work as well as had been hoped*
  - Alterations in stream habitat conditions, benthic community structure, and bed geomorphology
  - Streams have a flashier storm response in developed areas as compared to undeveloped ones
  - Stormwater discharge to streams increased
  - Watershed natural drainage patterns modified

- Document these changes, add more analyses (more nutrient and sediment) to better estimate effects on water purification ES
Maryland Case Study
Ongoing Research

- Increased targeted stream monitoring (N, P, sediment, turbidity)
- Initiating individual BMP monitoring (EPA and local partners)
- Watershed modeling (EPA partner) to better quantify BMP efficiency estimates
This information was used by the Montgomery County Planning Board in their recommendation to the Montgomery County Council that the Clarksburg Master Plan be revised and updated
- Ten Mile Creek

The County Council is currently considering the recommendation
- Adaptive management in action…the science is on the table!!!

Local level decision makers / developers need to know *what works* and how to *maximize the effect* of their mitigation actions
Urban Water Quality Ecosystem Services
Overall Summary / Conclusion

- Altering the landscape from natural to developed has **measurable impacts** on water purification ecosystem services.
- Urban mitigation actions can replace some lost ecosystem services.
- Some actions work better than others … landscape factors including land use and BMP presence, type, and spatial pattern are important for provision of specific services.
- Communication with local level decision makers is key for land use decision making in support of service availability.