Avoided Stormwater Impacts and Costs from Open Space Protection in the Brandywine Creek Watershed – Return on Environment

Chester County Water Resources Authority

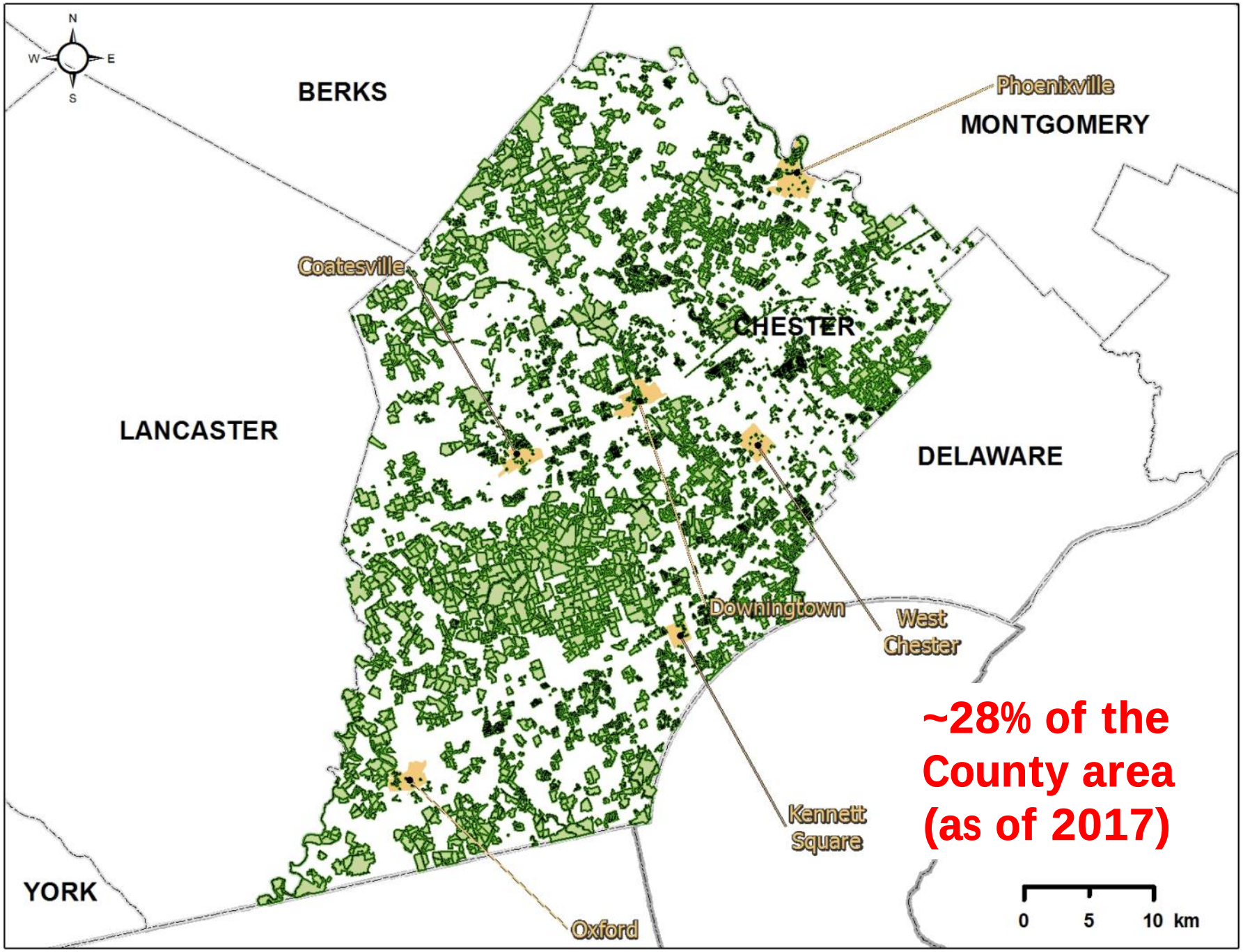
DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

STROUD WATER RESEARCH CENTER

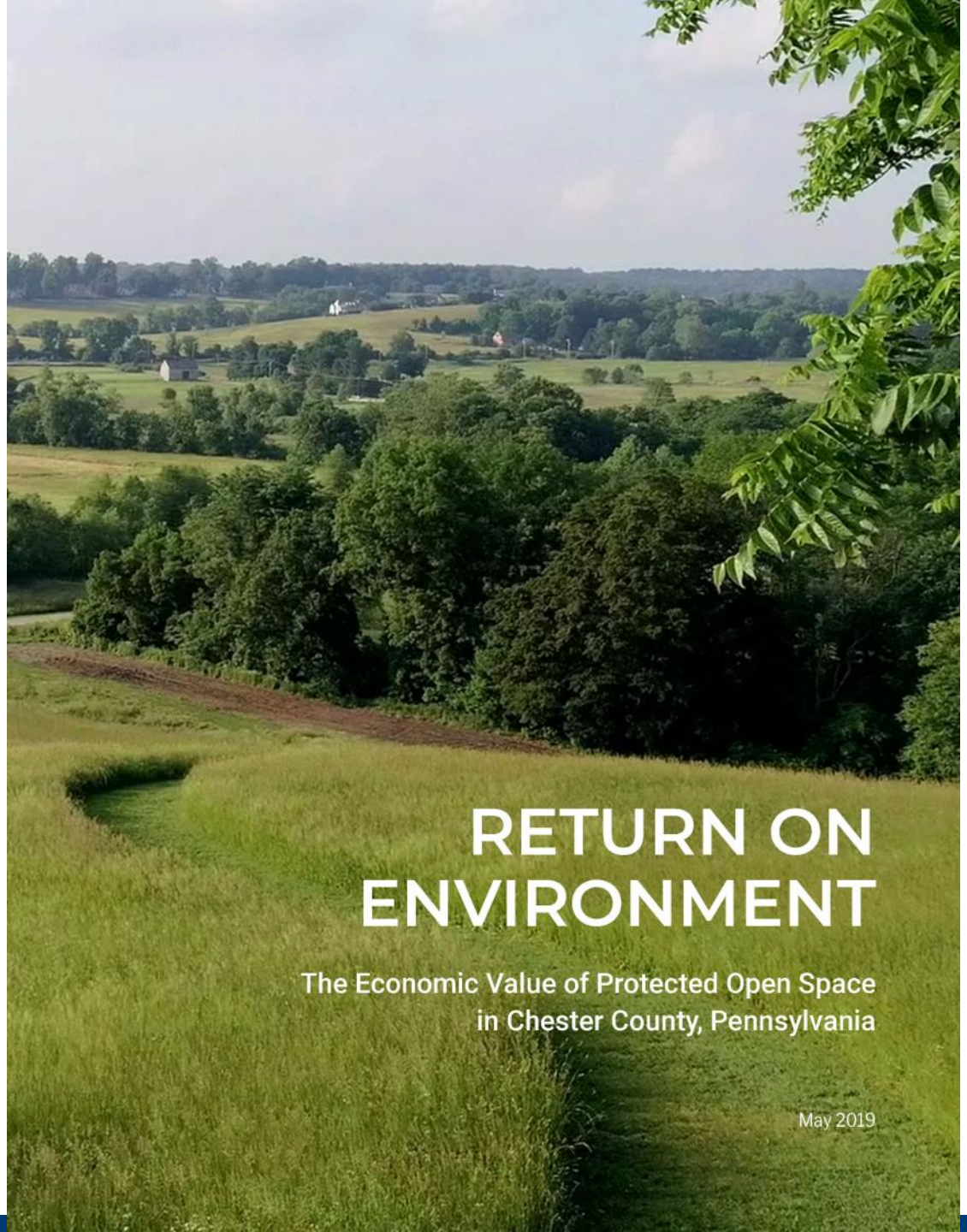
What is Protected Open Space (POS)?

- Public parks
- Private land owned or under conservation easement by land trusts
- Farmland preserved with Agricultural Land Preservation Board (ALPB) easements
- Protected land owned and managed by a homeowners association
- Other protected lands

STROUD WATER RESEARCH CENTER



~28% of the County area (as of 2017)

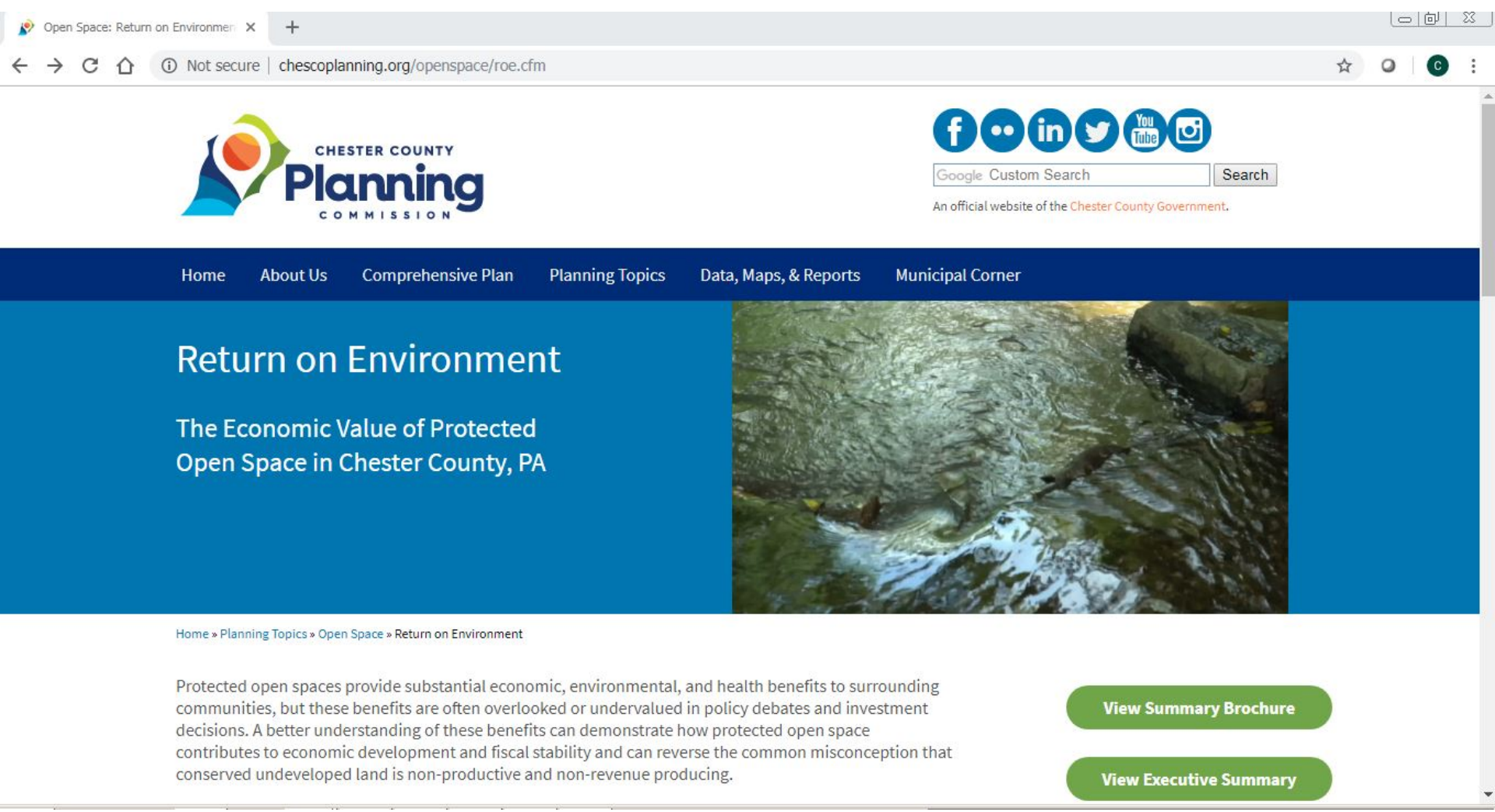


RETURN ON ENVIRONMENT

The Economic Value of Protected Open Space in Chester County, Pennsylvania

May 2019

STROUD WATER RESEARCH CENTER



Report and related materials are available online at:
http://chescoplanning.org/openspace/roe.cfm

STROUD WATER RESEARCH CENTER

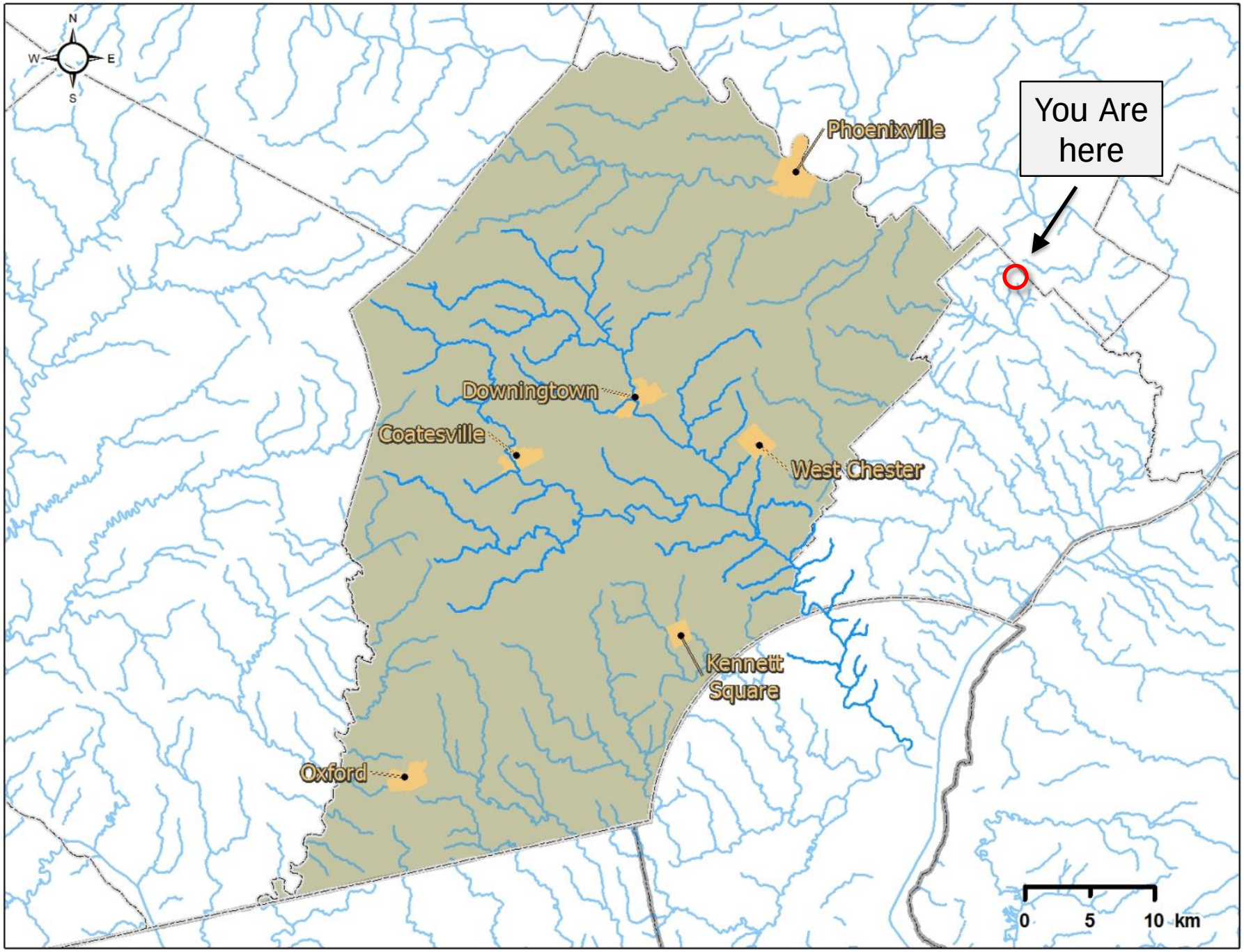
What will be covered today?

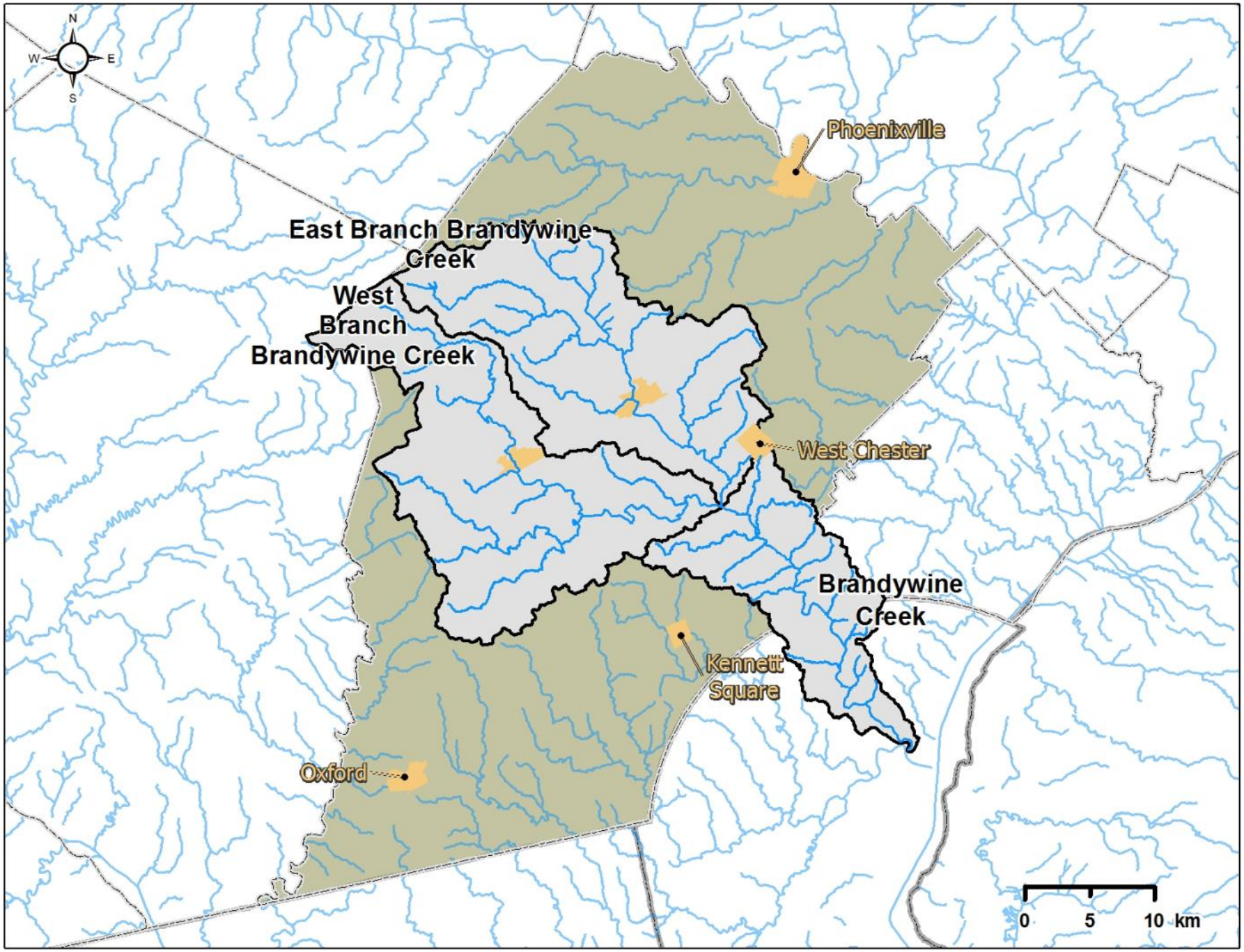
- Methodology behind the modeling for stormwater runoff and pollutant loading work
  - Geography modeled
  - Definition of the model scenarios run
  - Models used for defining quantity (i.e. runoff) and quality (i.e. pollutant loadings)
- Results
  - **Stormwater Mitigation** - reduction in stormwater quantity; improvement in stormwater quality
  - **Economic Benefits** - reduction in costs due to Stormwater Mitigation attributable to POS.

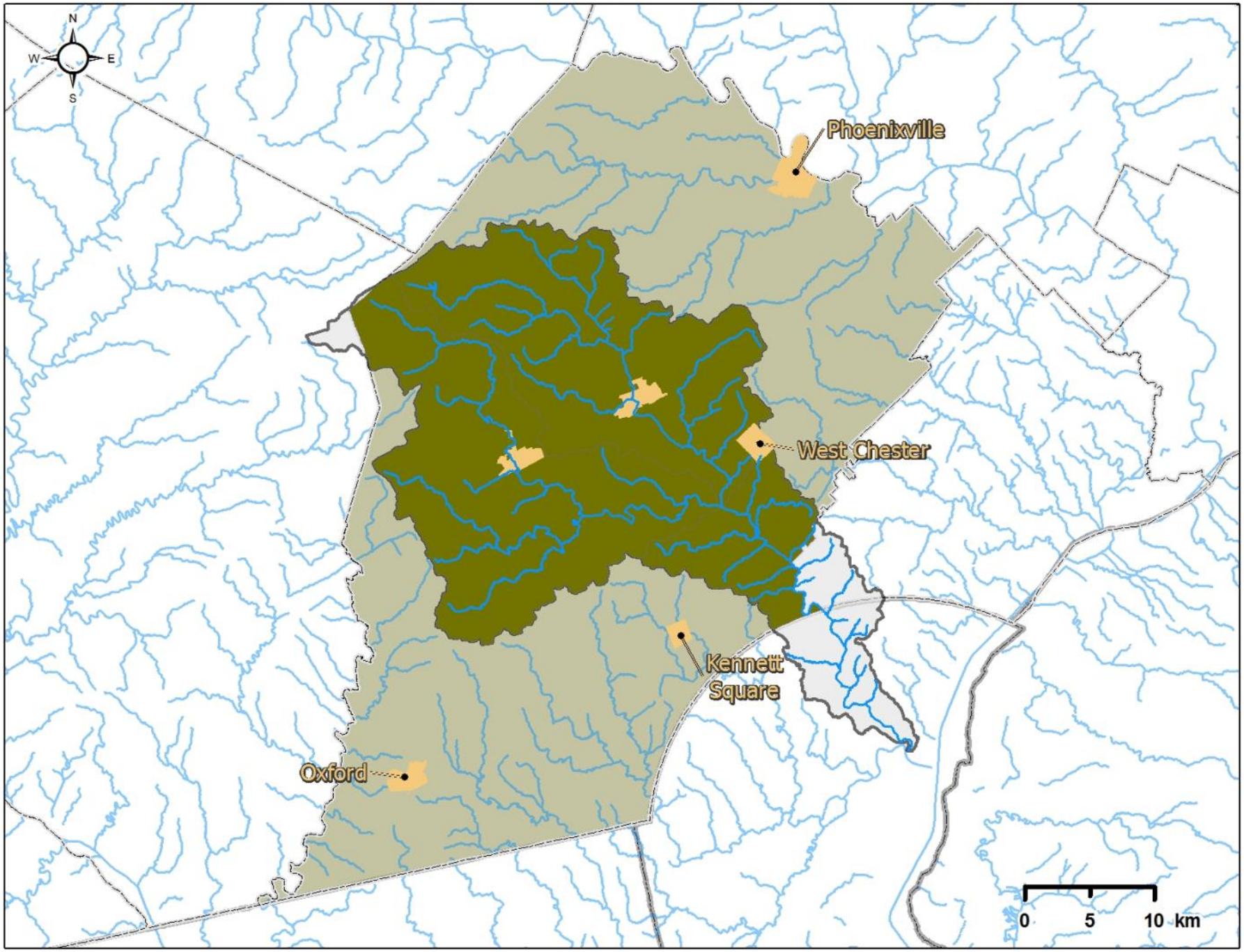
STROUD WATER RESEARCH CENTER

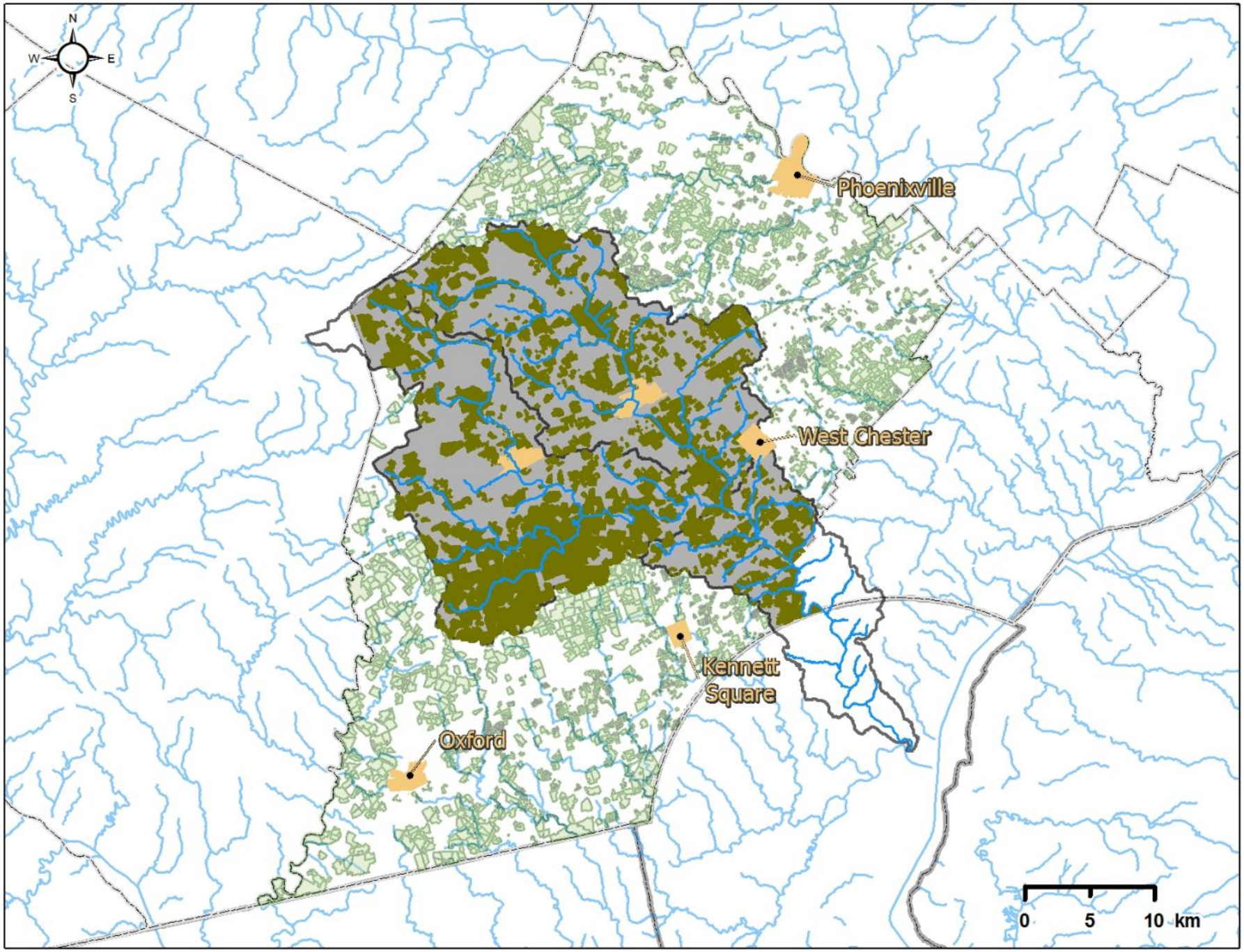
What area, within Chester County, was modeled (Geography covered)?

STROUD WATER RESEARCH CENTER


N
W
E
S
You Are here
Phoenixville
Downingtown
Coatesville
West Chester
Kennett Square
Oxford
0
5
10 km


N
W
E
S
Phoenixville
East Branch Brandywine Creek
West Branch Brandywine Creek
West Chester
Brandywine Creek
Kennett Square
Oxford
0
5
10 km


N
W
E
S
Phoenixville
West Chester
Kennett Square
Oxford
0
5
10 km


N
W
E
S
Phoenixville
West Chester
Kennett
Square
Oxford
0
5
10 km

Model Scenarios –

How to get at the Stormwater Mitigation potential of POS?

STROUD WATER RESEARCH CENTER

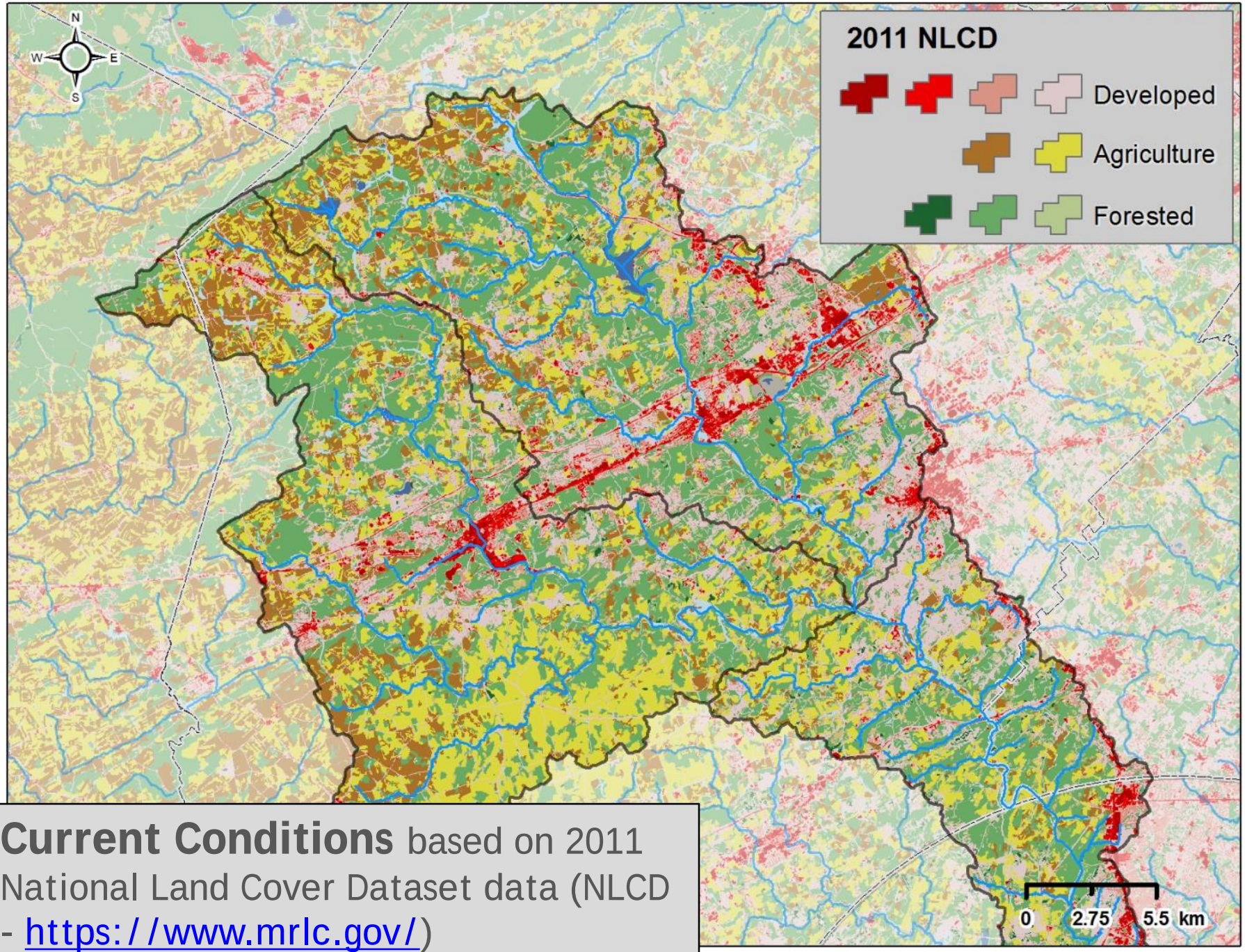
Three scenarios for assessing the benefits of POS relative to stormwater:

Current Conditions: current land cover conditions (including existing protected open space)

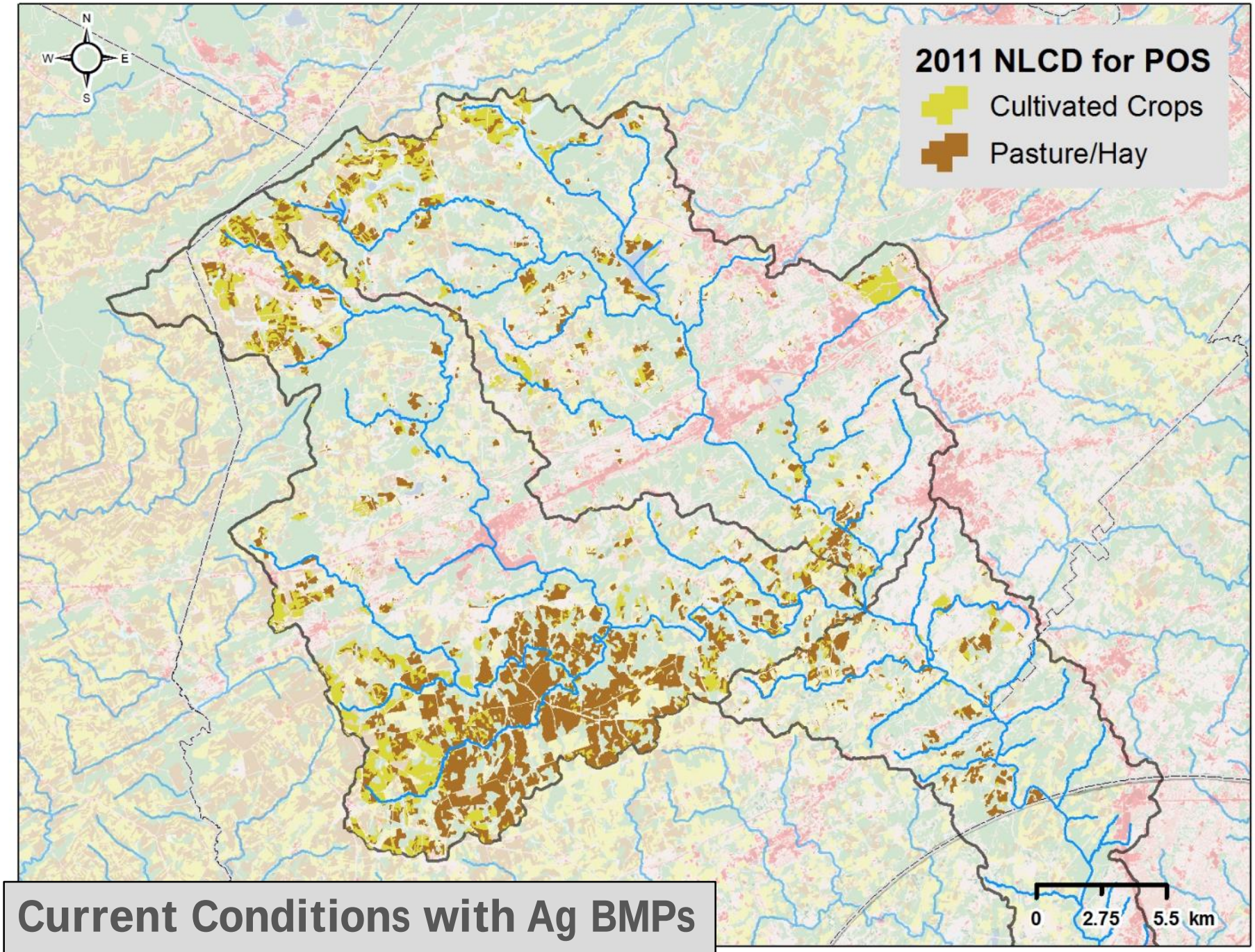
Current Conditions with Ag BMPs: current land cover conditions plus implementing agricultural best management practices (BMPs) on preserved agricultural lands

No Preservation: assumed land cover conditions if no open space preservation had been put in place

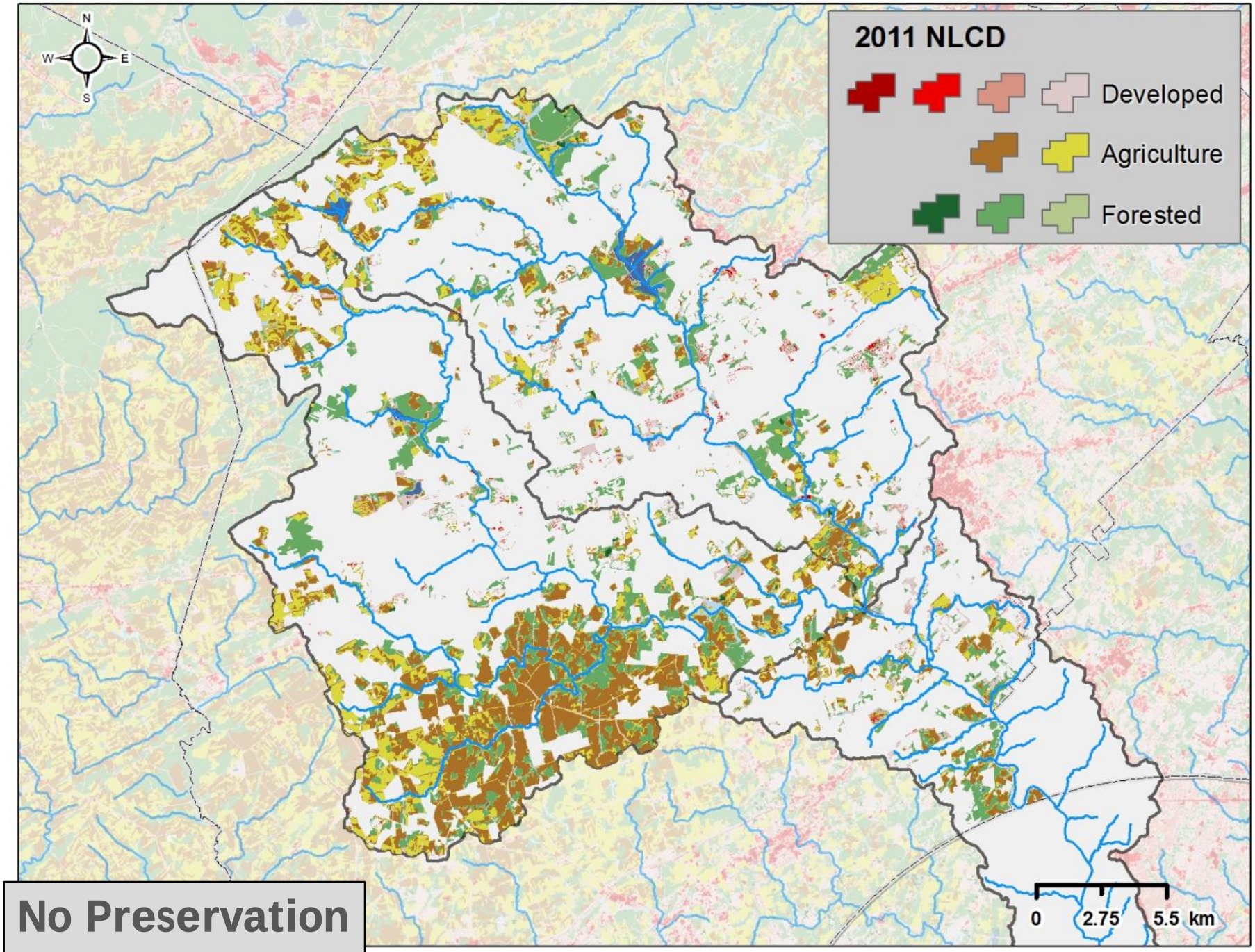
STROUD WATER RESEARCH CENTER



Current Conditions based on 2011 National Land Cover Dataset data (NLCD - https://www.mrlc.gov/)

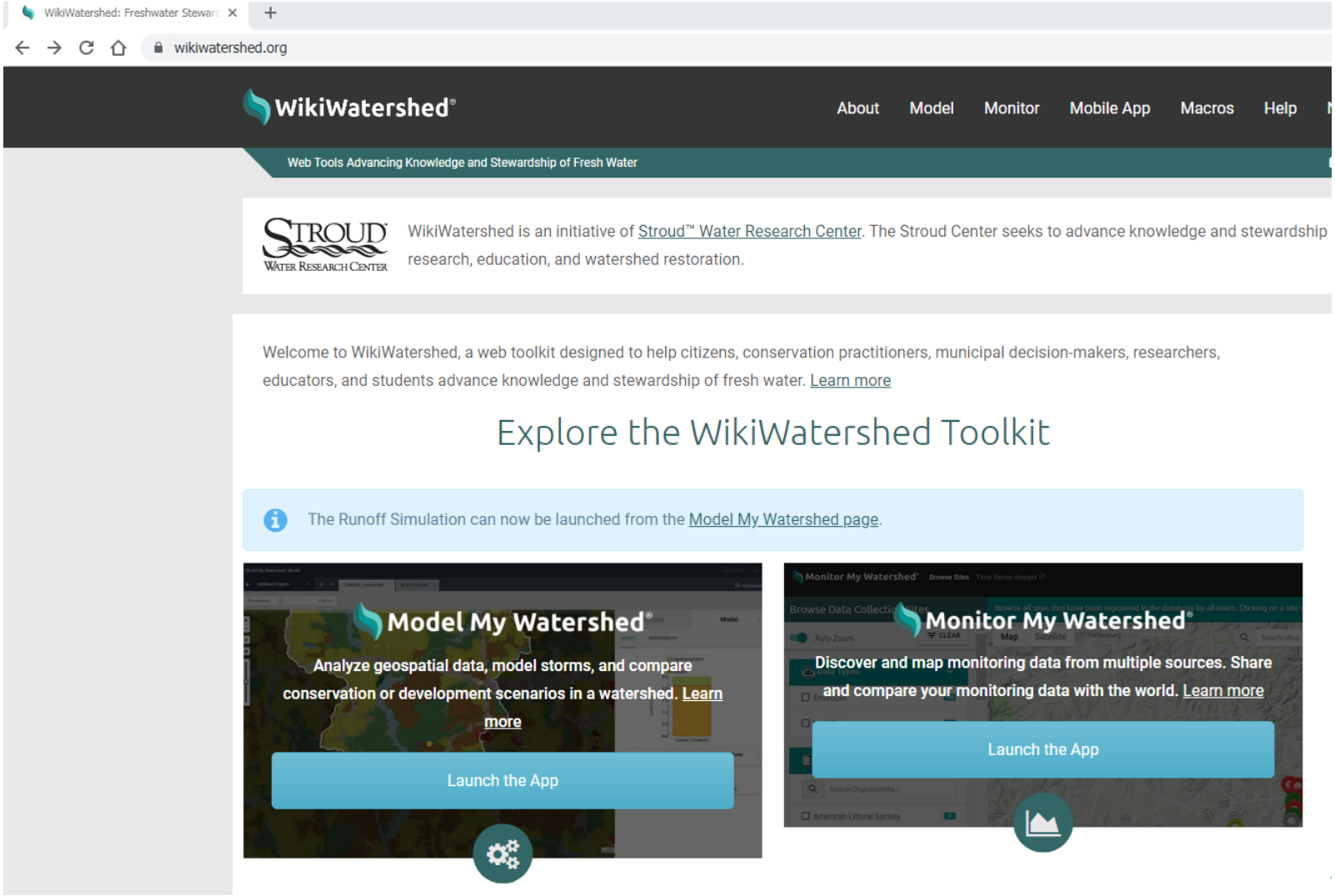


Current Conditions with Ag BMPs



No Preservation

Model My Watershed – https://wikiwatershed.org/



STROUD WATER RESEARCH CENTER

Site Storm Model –

For quantifying changes in stormwater volume.

7.1. Site Storm Model

The Model My Watershed (MMW) Site Storm Model simulates a single 24-hour storm by applying a hybrid of the Source Loading and Management Model (SLAMM, http://winslamm.com/), TR-55 (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf), and the simplest of the Food and Agriculture Organization of the United Nations evaporation models (http://www.fao.org/docrep/x0490e/x0490e00.htm#Contents) for runoff quantity and EPA's STEP-L model (http://it.tetratech-ffx.com/steplweb/) for water quality over the selected Area of Interest within the continental United States.

The results are calculated based on actual land cover data (from the USGS National Land Cover Database 2011, NLCD2011) and actual soil data (from the USDA Gridded Soil Survey Geographic Database, gSSURGO, 2016) for the selected land area of interest. For more information and data sources, see Section 2.2 Coverage Grids.

TR-55 Component

This model is used to calculate runoff for all "natural" land-use types. All of our TR-55 curve number info is here: https://github.com/WikiWatershed/tr-55/blob/develop/tr55/tables.py

SLAMM Component

TheSource Loading and Management Model (SLAMM, http://winslamm.com/) is used to calculate runoff for urban land-use types. For additional information on SLAMM, see http://dnr.wi.gov/topic/stormwater/standards/slamm.html. All of our SLAMM curve number info is here: https://github.com/WikiWatershed/tr-55/blob/develop/tr55/tables.py

Was this helpful? Yes No

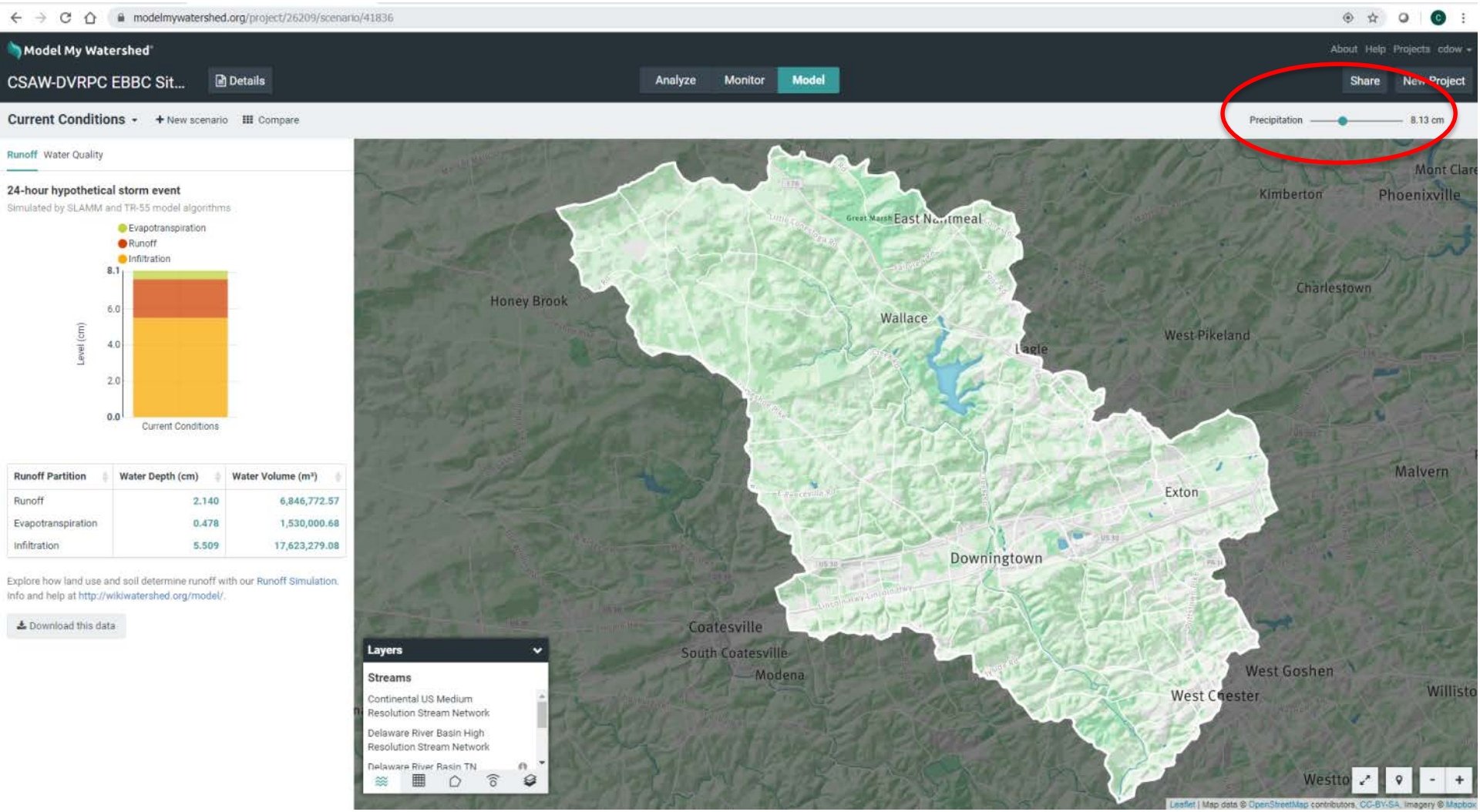
0 of 0 users found this section helpful

Suggest edit

Last updated on 2019-04-26

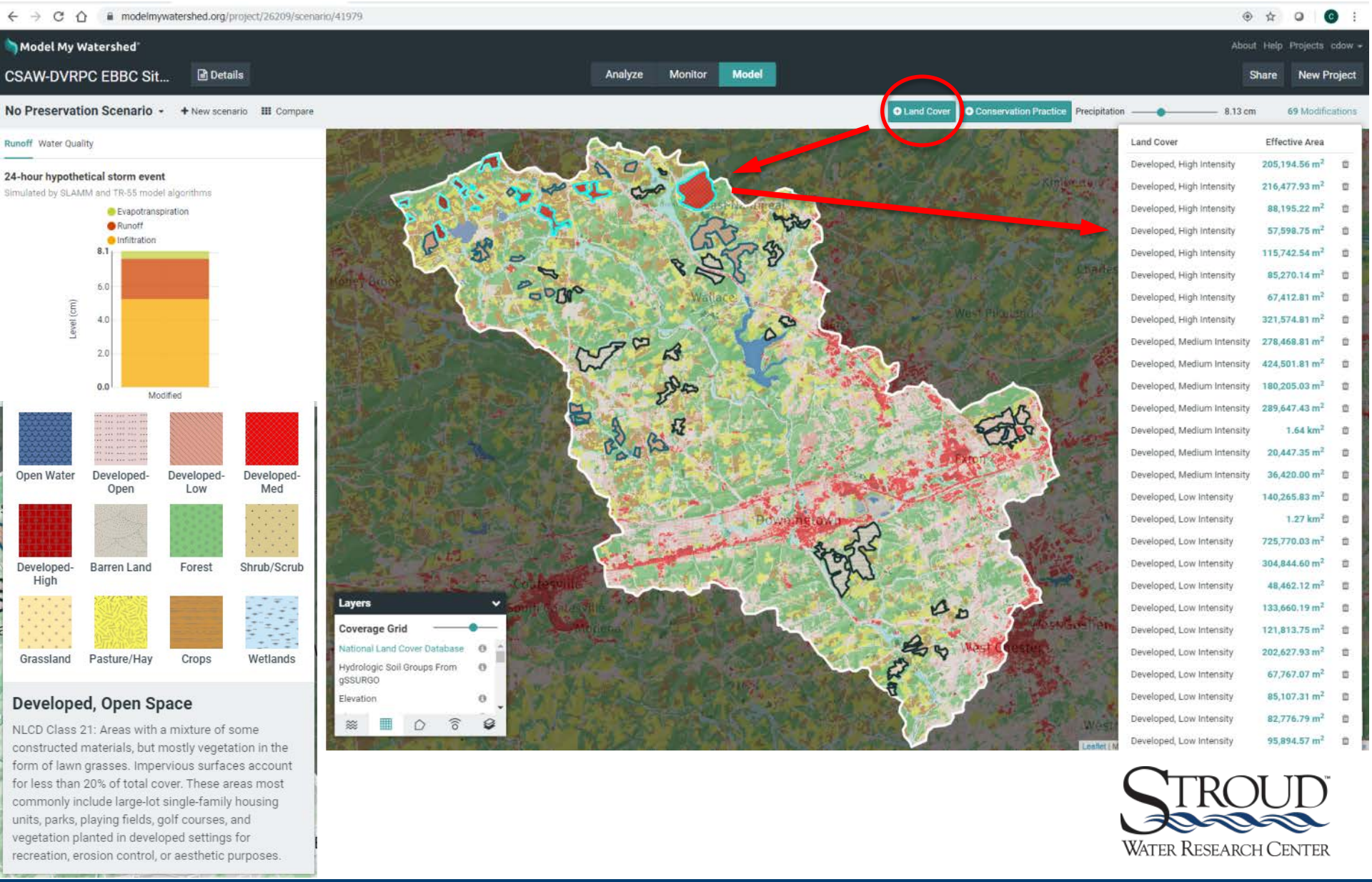
STROUD WATER RESEARCH CENTER

Modeling a single, 24-hour duration storm using a 2-year return period event of 3.2” (8.13 cm)



STROUD WATER RESEARCH CENTER

Changes in Land Cover (i.e. for the No Preservation scenario), have to be digitized for the Site Storm Model



STROUD WATER RESEARCH CENTER

Watershed Multi-Year Model –

For quantifying changes in stormwater quality (N, P, sediment).

7.2. Watershed Multi-Year Model

The Watershed Multi-Year Model in Model My Watershed (MMW) simulates 30-years of daily water, nutrient and sediment fluxes using the Generalized Watershed Loading Function Enhanced (GWLF-E) model that was developed for the MapShed (http://wikiwatershed.org/mapshed/) desktop modeling application by Barry M. Evans, Ph.D., and his group at Penn State University. The GWLF-E model is also one of five watershed models available within EPA's BASINS multi-purpose modeling application (https://www.epa.gov/exposure-assessment-models/basins-framework-and-features#models).

Model My Watershed will eventually become the primary framework for running the latest GWLF-E model version, replacing MapShed and BASINS (by 2018?) because these two desktop applications are built on the aging MapWindow GIS package (http://www.mapwindow.org/) that is no longer supported. For that reason, in late 2014 we ported all GWLF-E code from Visual Basic to Python, with all subsequent code development in this open source repository: https://github.com/WikiWatershed/gwlf-e/. Similarly, all of the MapWindow-based geoprocessing routines have been rewritten to operate with the open-source GeoTrellis (https://geotrellis.io/) geographic data processing engine and framework, with all new code in this repository: https://github.com/WikiWatershed/model-my-watershed.

Was this helpful? Yes No

Suggest edit

1 of 1 users found this section helpful

Last updated on 2019-04-26

7.2.1. The GWLF Model

The core watershed multi-year simulation model used in MMW and MapShed (GWLF-E) is an enhanced version of the Generalized Watershed Loading Function (GWLF) model first developed by researchers at Cornell University (Haith and Shoemaker, 1987). The original DOS-compatible version of GWLF was rewritten in Visual Basic by Evans et al. (2002) to facilitate integration with ArcView© and other GIS software packages, and tested extensively in the U.S. and elsewhere. Since 2002 it has been substantially enhanced; see Section 5.2.2 GWLF-Enchancements.

The advantage of GWLF (and GWLF-E) is the ease of use and reliance on input datasets less complex than those required by other watershed-oriented water-quality models such as SWAT, SWMM, and HSPF (Deliman et al., 1999). The model has also been endorsed by the U.S. EPA as a good "mid-level" model that contains algorithms for simulating most of the key mechanisms controlling nutrient and sediment fluxes within a watershed (U.S. EPA, 1999).

The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for

STROUD WATER RESEARCH CENTER

WikiWatershed is an initiative of Stroud™ Water Research Center. The Stroud Center seeks to advance knowledge and stewardship research, education, and watershed restoration.

MapShed GIS-Based Watershed Modeling Tool

See also: About MapShed | Software Downloads | Data Downloads | Documentation | Video Tutorials

About MapShed

Dr. Barry Evans and his group at Penn State Institute of Energy and the Environment worked to improve the ArcView Generalized Watershed Loading Function (AVGWLF), a GIS-based watershed modeling tool that uses hydrology, land cover, soils, topography, weather, pollutant discharges, and other critical environmental data to model sediment and nutrient transport within a watershed.

AVGWLF has been used for federally-mandated total maximum daily load (TMDL) studies in Pennsylvania since 1999, and regionalized versions of this software have been developed for EPA Region 6 in the southwestern part of the U.S., in New York state, and for New England. AVGWLF has been used by the Mexican Institute of Water Technology for various watershed studies since 2000, and it has been used by other governmental agencies and scientists located throughout the world.

Changes in Land Cover (i.e. for the No Preservation scenario), are done in tabular format, modifying the current condition area values.

Lower BC Land Cover

Current Conditions

Land Cover

Hay / Pasture (ha)	2742.7
Cropland (ha)	843.6
Wooded Areas (ha)	6577.2
Wetlands (ha)	497.1
Open Land (ha)	61.1
Barren Areas (ha)	0
Low-Density Mixed (ha)	1018.9
Medium-Density Mixed (ha)	856.1
High-Density Mixed (ha)	343.7
Low-Density Open Space (ha)	4105

Total: 17,045.4 ha

Cancel Save

Lower BC Land Cover

No Preservation

Land Cover

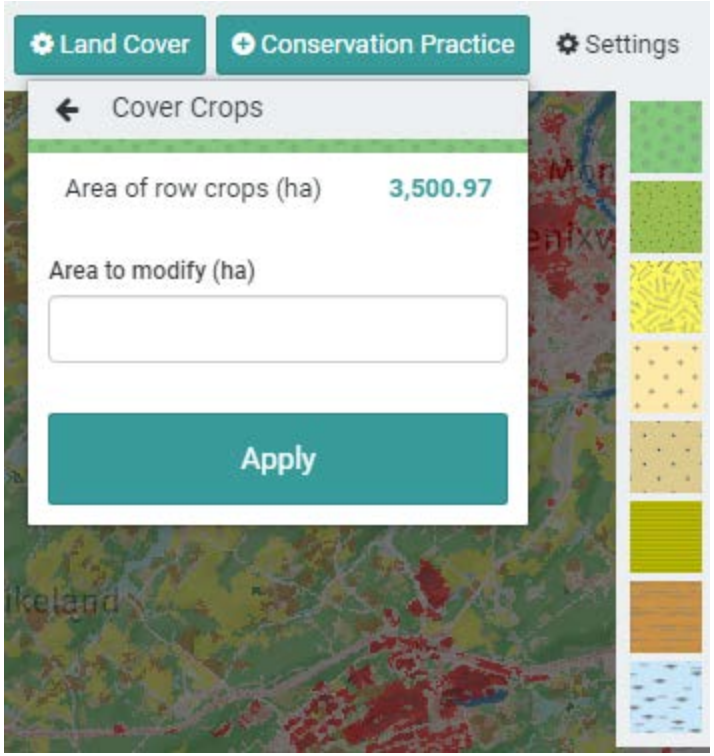
Hay / Pasture (ha)	2587.5
Cropland (ha)	799.5
Wooded Areas (ha)	6369.8
Wetlands (ha)	497.1
Open Land (ha)	61.1
Barren Areas (ha)	0
Low-Density Mixed (ha)	1066.7
Medium-Density Mixed (ha)	887.5
High-Density Mixed (ha)	350.7
Low-Density Open Space (ha)	4425.5

Total: **17,045.4 ha**

Cancel Save

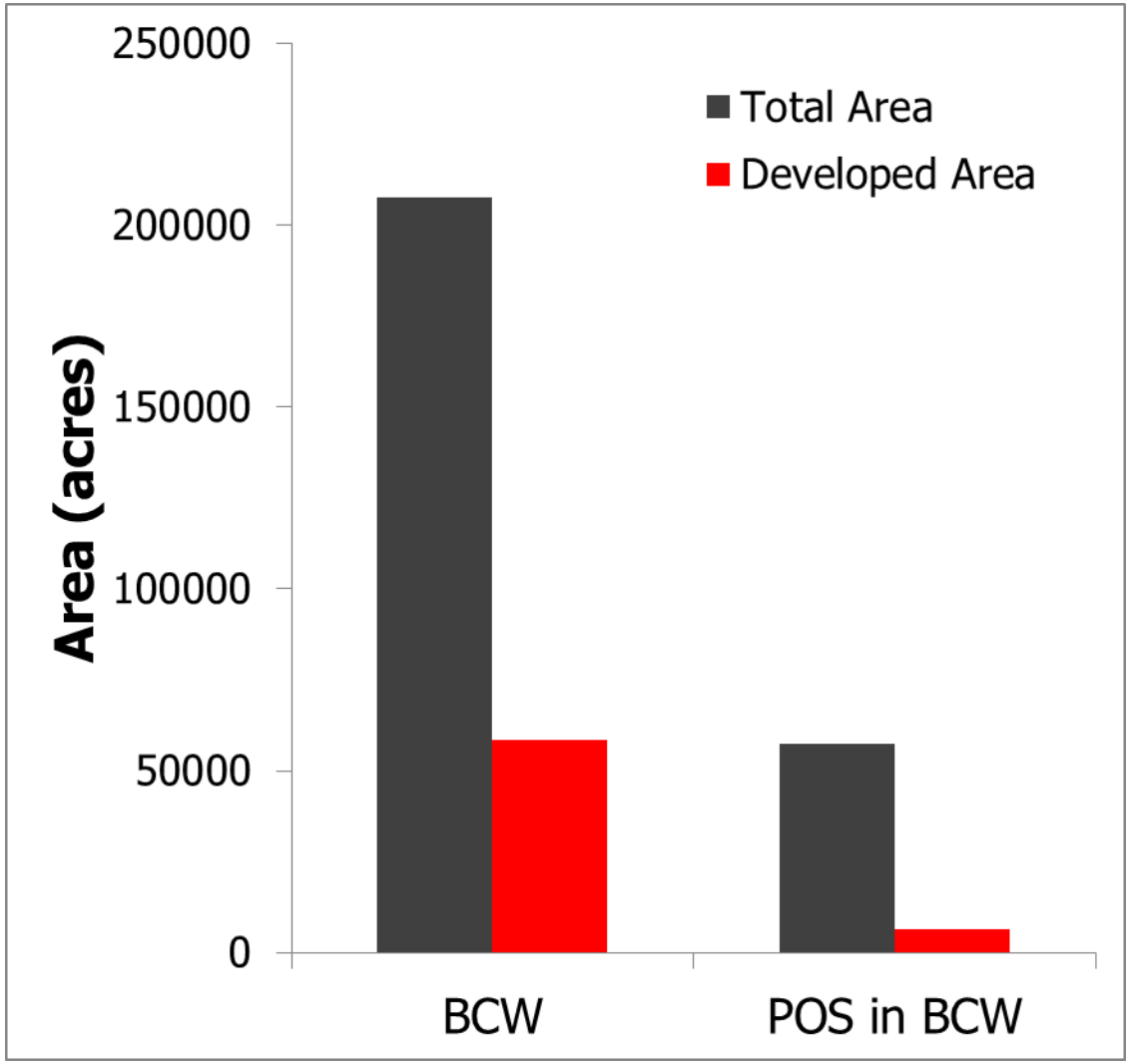
STROUD WATER RESEARCH CENTER

Adding BMPs (i.e. for the Current Conditions with Ag BMPs scenario), are also by inputting an ‘area to modify’.



STROUD WATER RESEARCH CENTER

Area in the Brandywine Creek watershed (BCW) and Open Space area within BCW (POS in BCW).



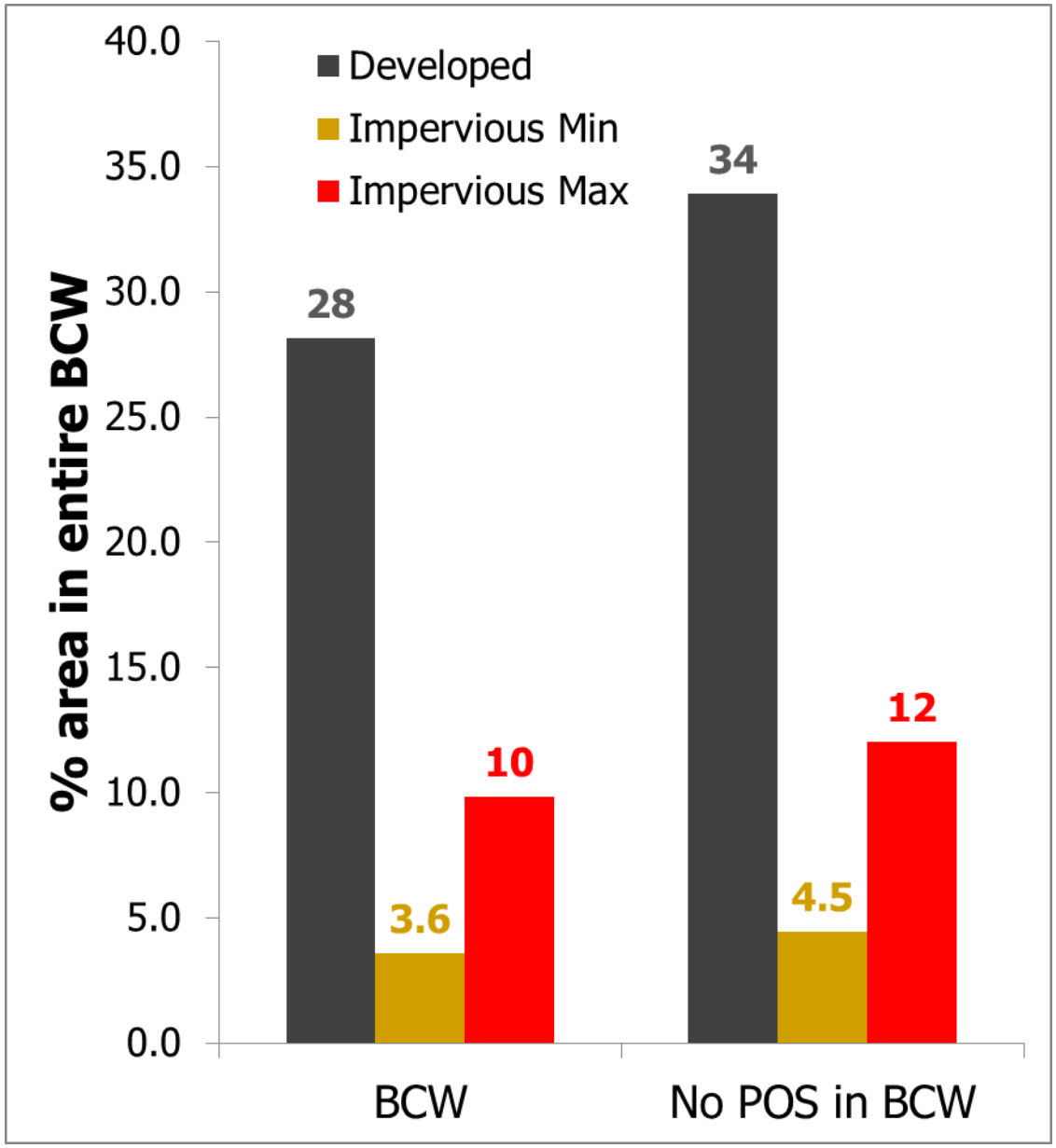
28% Open Space in entire watershed

28% Developed area in entire watershed.

11% Developed in the Open Space areas within the watershed

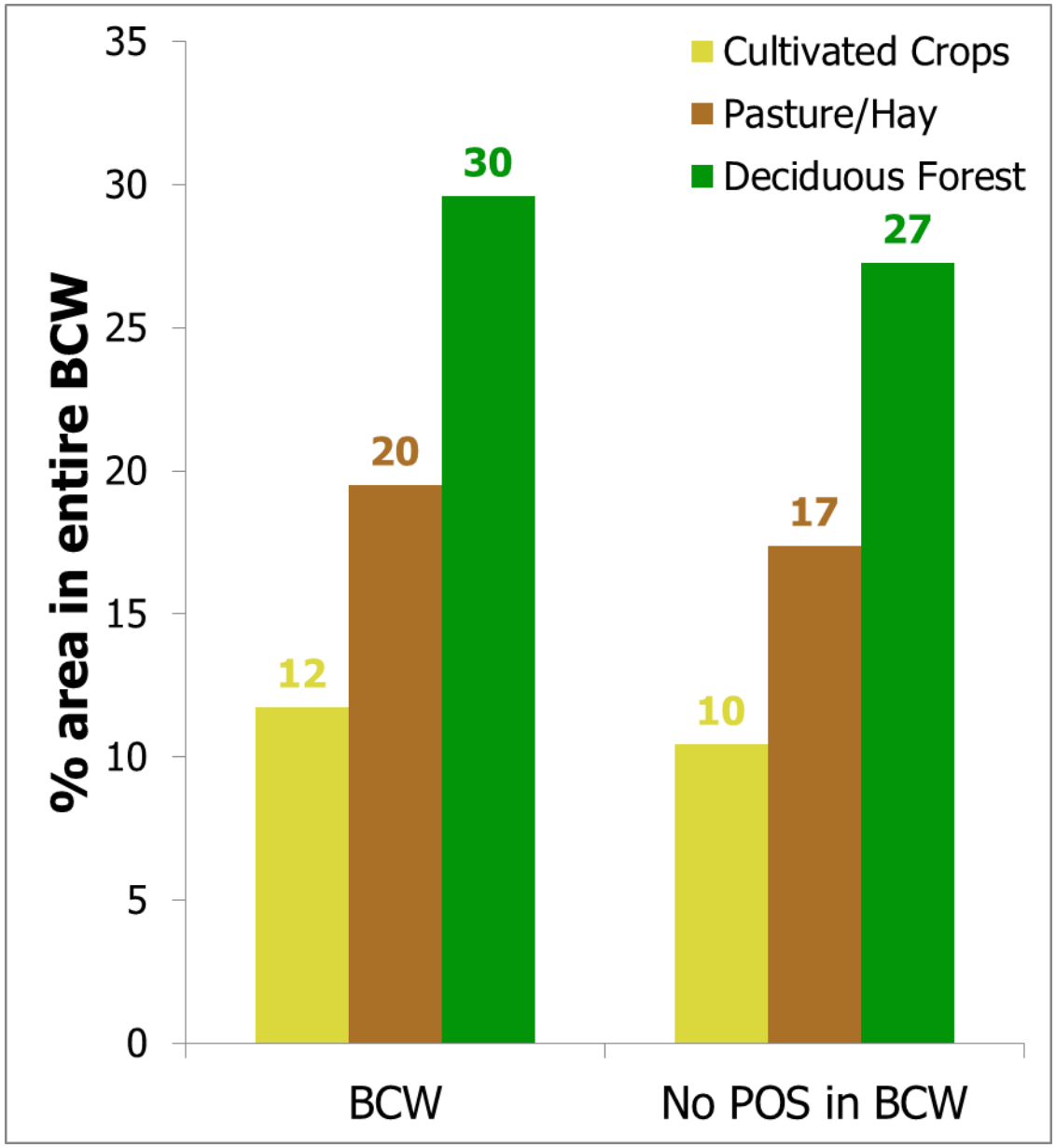
STROUD WATER RESEARCH CENTER

If there wasn't any POS, what would the potential change be in developed and associated impervious area (as a percentage of the entire watershed area)?



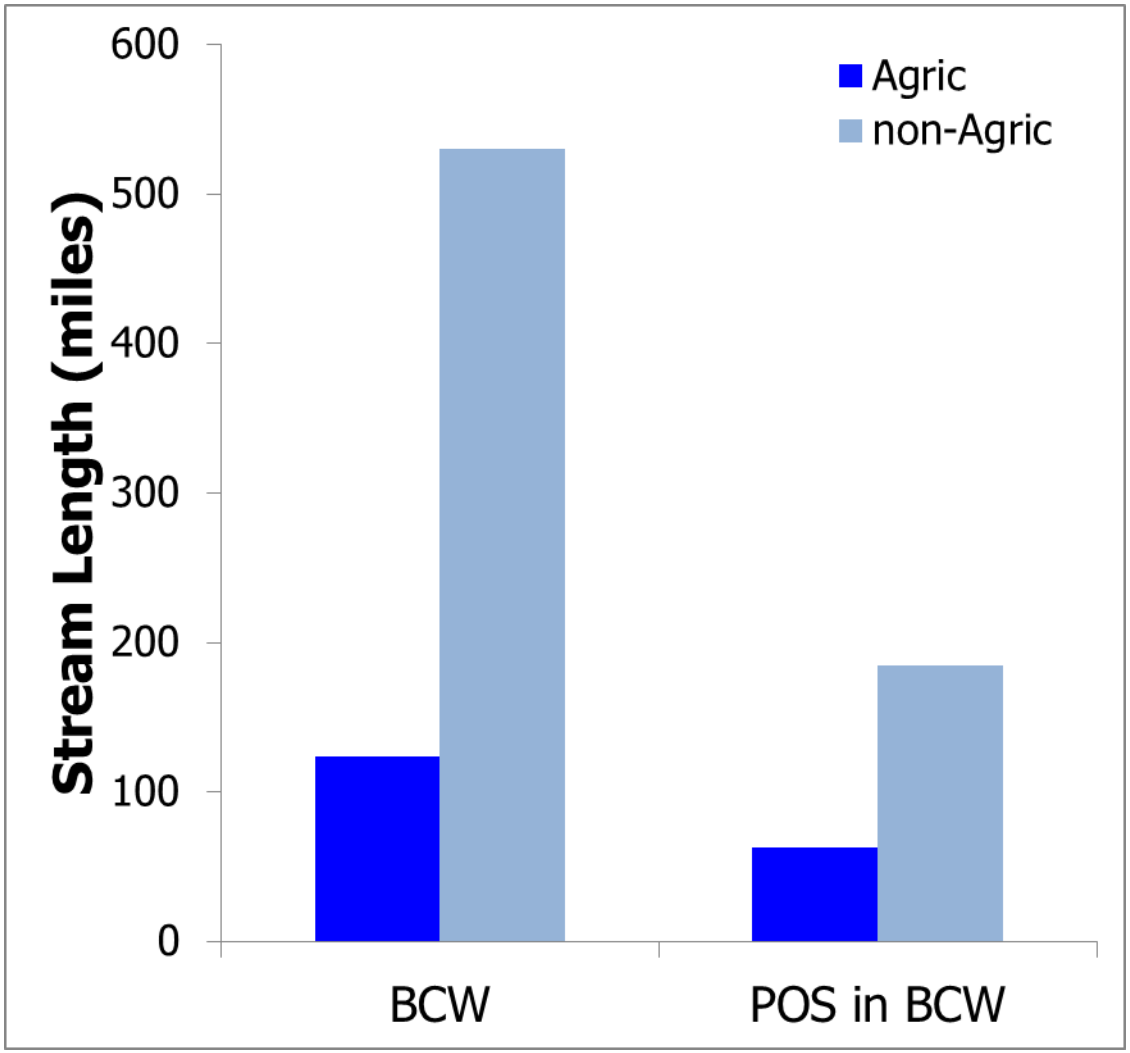
STROUD WATER RESEARCH CENTER

Potential increases in development under the No Preservation scenario would lead to corresponding decreases in agriculture and forested areas



STROUD WATER RESEARCH CENTER

Streams in agricultural lands relative to all other land covers. Based on the high resolution NHD layer.

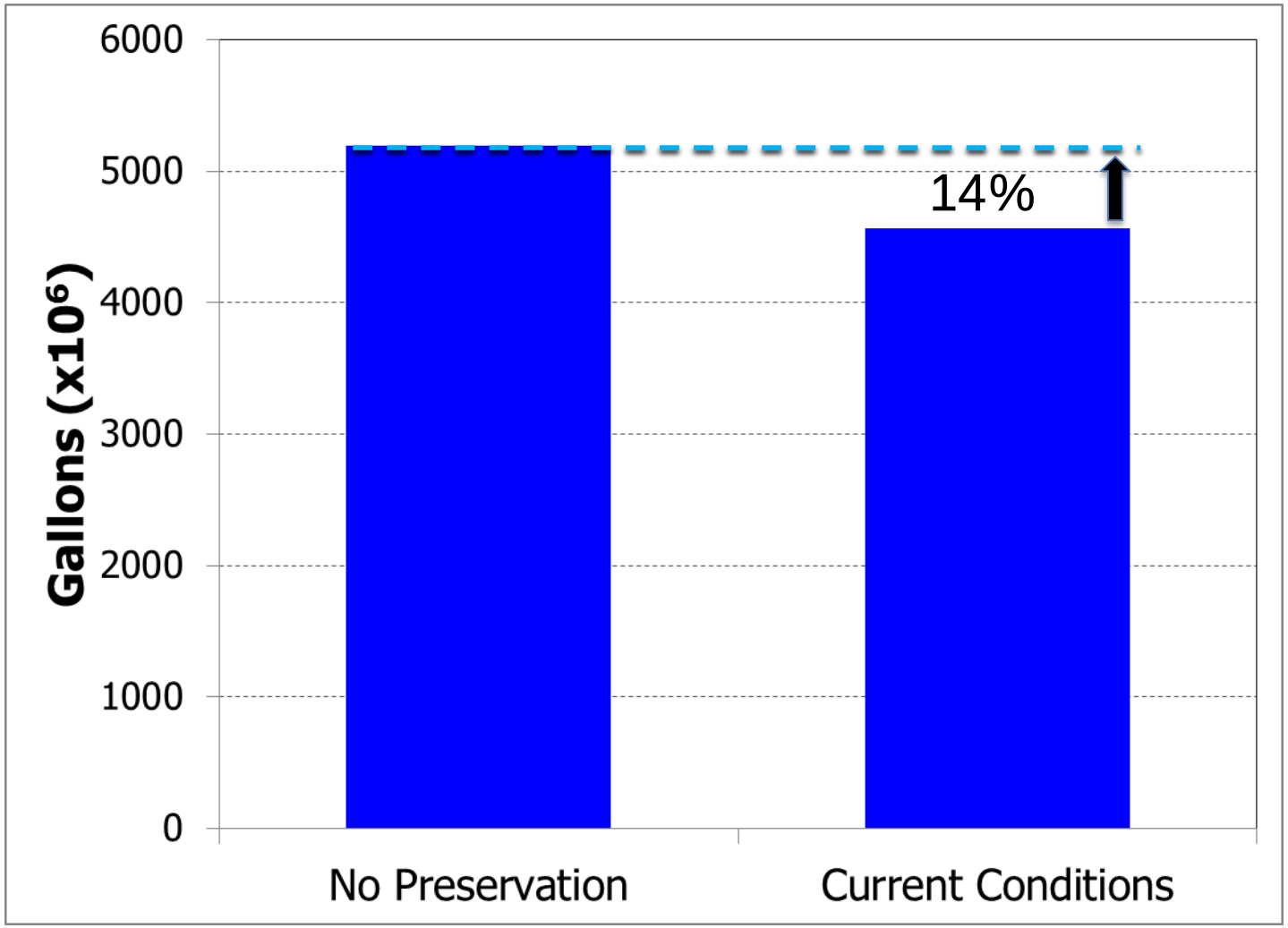


Just over 50% of the streams on ag lands in the entire BCW are also part of POS

STROUD WATER RESEARCH CENTER

Change in Stormwater Runoff - Entire BC

Total volume for a 2-yr, 24-hr return-interval event.



STROUD WATER RESEARCH CENTER

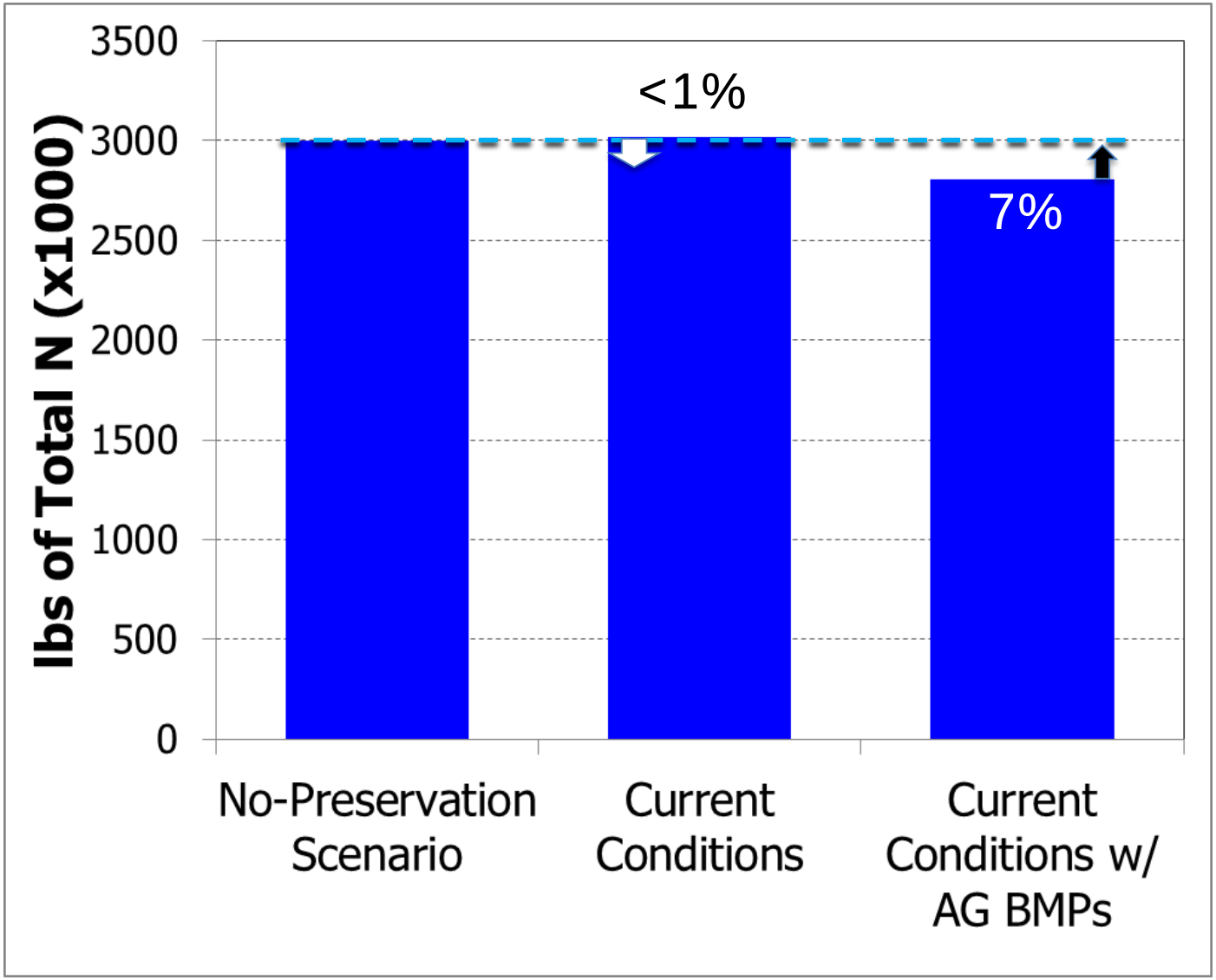
Change in Stormwater Runoff attributable to POS, part 2:

For the entire Brandywine Cr. Watershed.
Per acre of POS, on an annual basis as well as per storm.

	Avoided Runoff Per Acre of Protected Open Space	% Increase in runoff in the absence of POS
Average Annual Runoff (from 41.1 inches/yr)	36,000 gallons per acre per year	17%
2-Year Storm Event Runoff (from a 3.2", 24 hr period event)	11,000 gallons per storm	14%

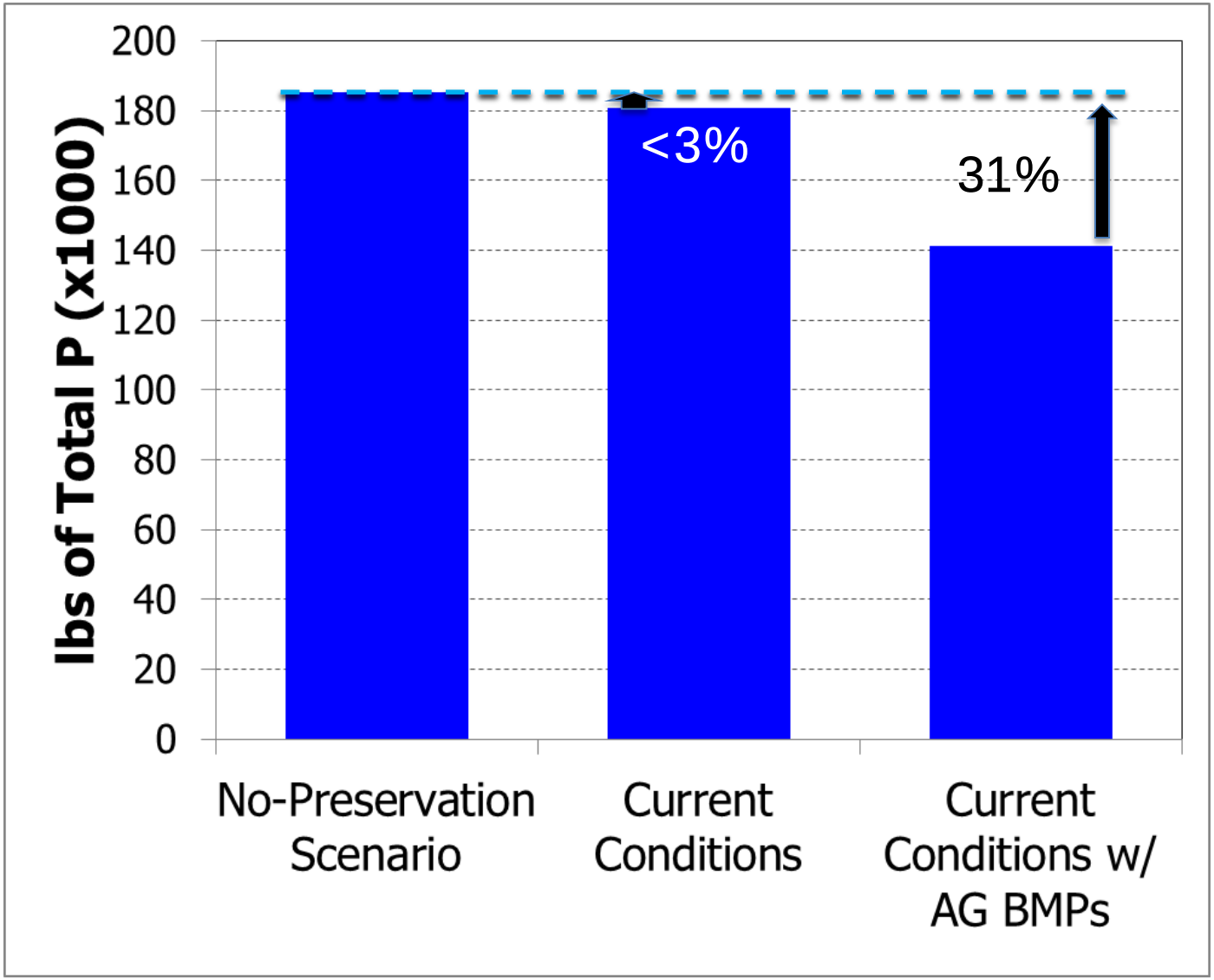
STROUD WATER RESEARCH CENTER

Change in Total Annual Nitrogen Load – Entire BC



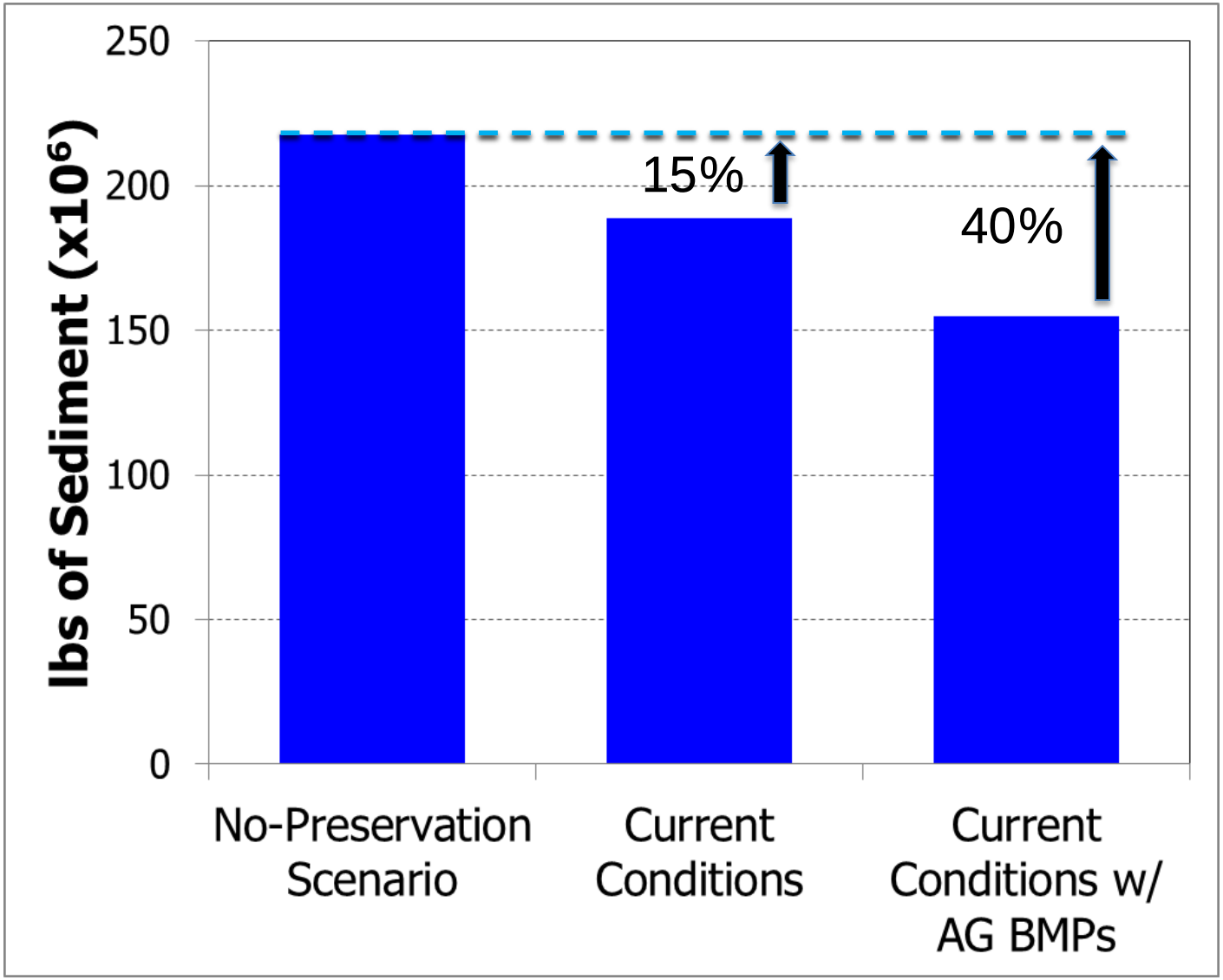
STROUD WATER RESEARCH CENTER

Change in Total Annual Phosphorus Load – Entire BC



STROUD WATER RESEARCH CENTER

Change in Total Annual Sediment Load – Entire BC



STROUD WATER RESEARCH CENTER

Change in Stormwater Quality (N, P, & Sediment) attributable to POS, part 2:

For the entire Brandywine Cr. Watershed. **Per acre of POS**.

	Avoided Annual Pollutant Loading Per Acre of POS	% Increase in Pollutant Loadings in the absence of POS & Ag BMPs
Total Nitrogen	3.5 lb/acre/yr	7.1%
Total Phosphorus	0.8 lb/acre/yr	31%
Sediment	1,092 lb/acre/yr	40%

STROUD WATER RESEARCH CENTER

Summary of Stormwater Mitigation potential of POS:

- Successfully used MMW to assess the potential impact to streams and rivers from a landscape-based policy.

- Demonstrated the usefulness of such models for quantifying large-scale impacts not easily (or even feasibly) measured in the field.

- Protected Open Space, or the minimization of development in otherwise developable lands, provides for reduction in both stormflow quantity and quality.

- Implementing a restoration plan (i.e. BMPs) on agricultural-based POS, further enhances the value of POS towards stormwater runoff and pollution mitigation

STROUD WATER RESEARCH CENTER

Economic Benefits of Avoided Stormwater & Pollutant Runoff

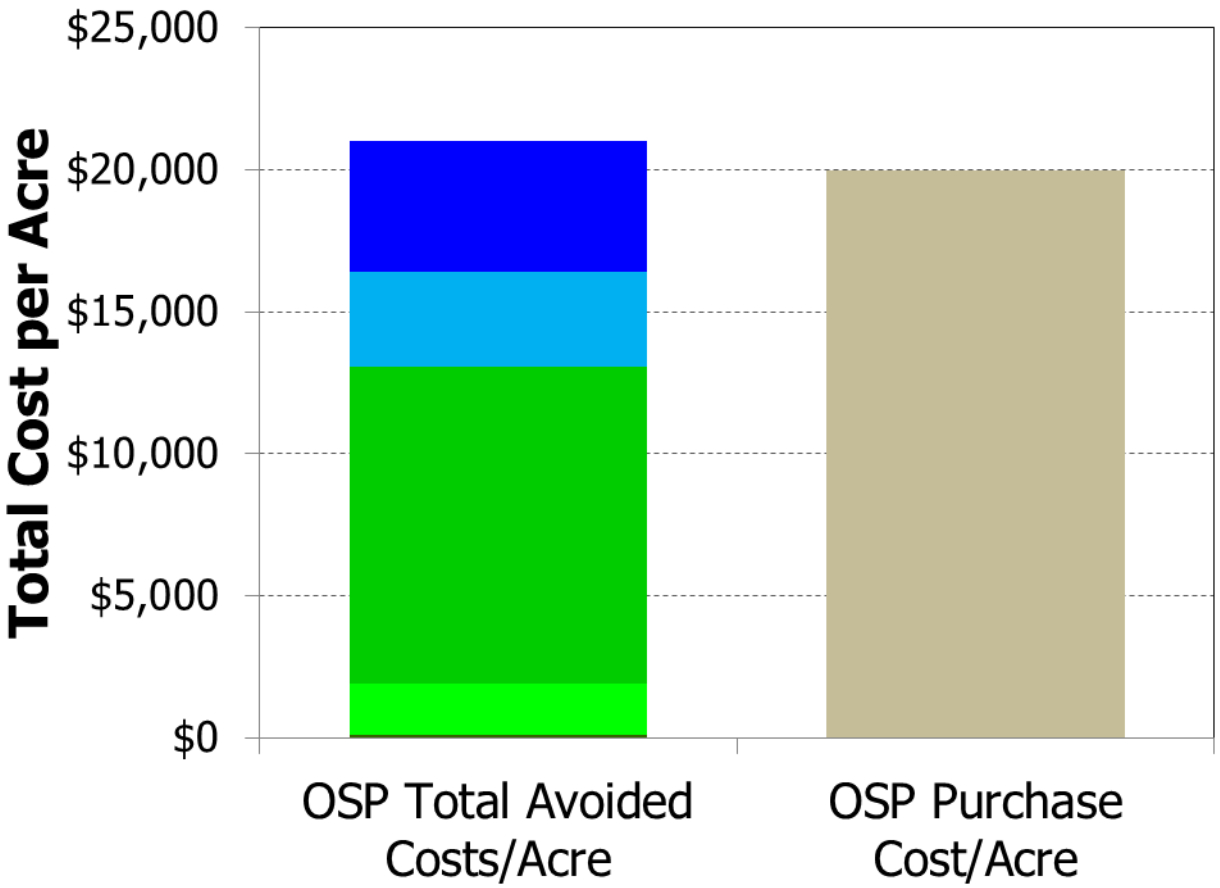
- Economic analyses
  - conducted by Econsult Solutions, Inc. in conjunction with DVRPC and CCWRA
- Three categories of avoided costs were calculated
  - 2-yr stormwater runoff management infrastructure –
    - Avoided capital construction cost
    - Avoided annual O&M cost
  - Avoided annual pollutant removal cost (TP, TN, sediment) otherwise needed to comply with NPDES PRP and/or TMDL pollution reduction requirements

Limitations

- Cost estimates for stormwater mitigation services can vary widely
- Likely that the economic benefits presented in this study are conservative and under-estimate actual costs
- Other literature sources present higher unit costs
- Methodology used was biased toward a conservative approach to avoid over-estimates

Benefits of Open Space Protection (OPS) in terms of $:

Comparing OPS purchase cost to capital costs plus O & M costs after 7 years.



One-time cost (per acre):

- Runoff - Capital ($4,600)

Annual costs (per acre):

- Runoff - O&M ($479)
- Sediment ($1,595)
- Total P ($256)
- Total N ($16)

OPS would pay for itself in < 10 years.

STROUD WATER RESEARCH CENTER

Conclusions

Open space protection should be a part of every municipality's "tool box" for reducing future stormwater costs and pollution –

- The scale of open space protection in the Brandywine watershed is beyond reach for many municipalities.
- However, each acre of open space protection will achieve significant environmental and economic benefits.
- Annual savings from avoided stormwater costs could offset the purchase cost of the land and at least a portion of lost local property tax revenue within 10 years.
- Cost savings from other environmental benefits will reduce that pay-back time frame (flood mitigation, carbon storage, water recharge, etc.)