

# Using GIS for Prioritization in Subwatershed Restoration

Elena Horvath  
Advisor: Joseph Bishop, PhD

November 10, 2011

The Pennsylvania State University  
Master in Geographic Information Systems  
[www.gis.psu.edu](http://www.gis.psu.edu)

(Note: Slides 24 – 46 include presentation notes)

# Project Focus

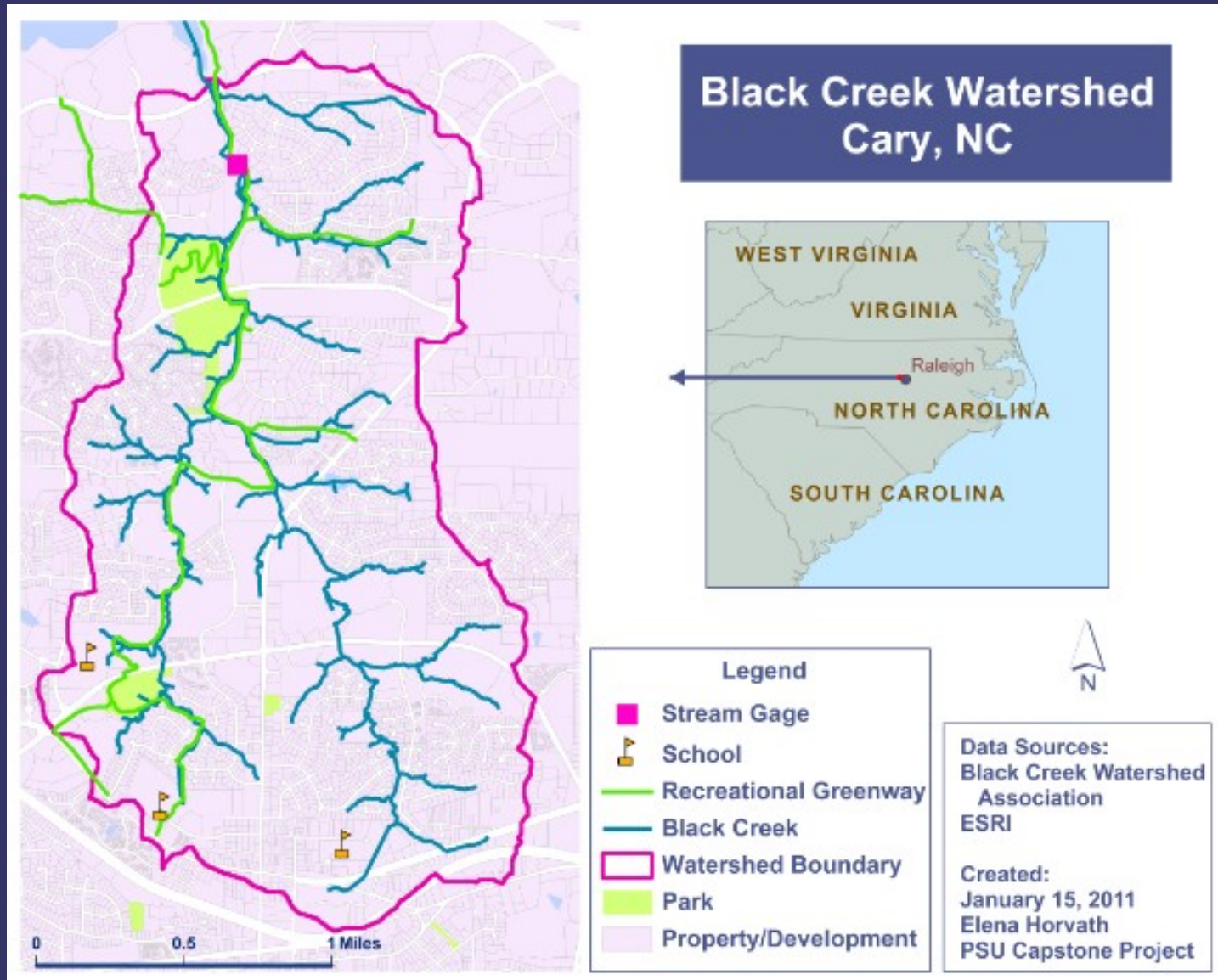
## Geographic Information Systems (GIS)

- How the technical strengths of GIS can prioritize and maximize watershed restoration efforts

## Black Creek – Cary, NC

- “Typical” suburban subwatershed
  - 3.3 square miles
  - Largely built out
  - On 303(d) Impaired Waters List
  - Black Creek Watershed Association (BCWA)
  - Primary indicator – stormwater runoff

# Study Area



# Objective Overview

## Objective 1: Prioritize subwatersheds

- Zoom out (multiple subwatersheds)
- Evaluate impervious cover
- Prioritizing legacy “target rich” development and location

## Objective 2: Develop the stormwater retrofit goal

- Zoom in (one subwatershed)
- Focus on impervious cover rather than pollutant-specific TMDLs (Eagleville Brook Model)
- Setting a target based on acreage to “disconnect” legacy runoff

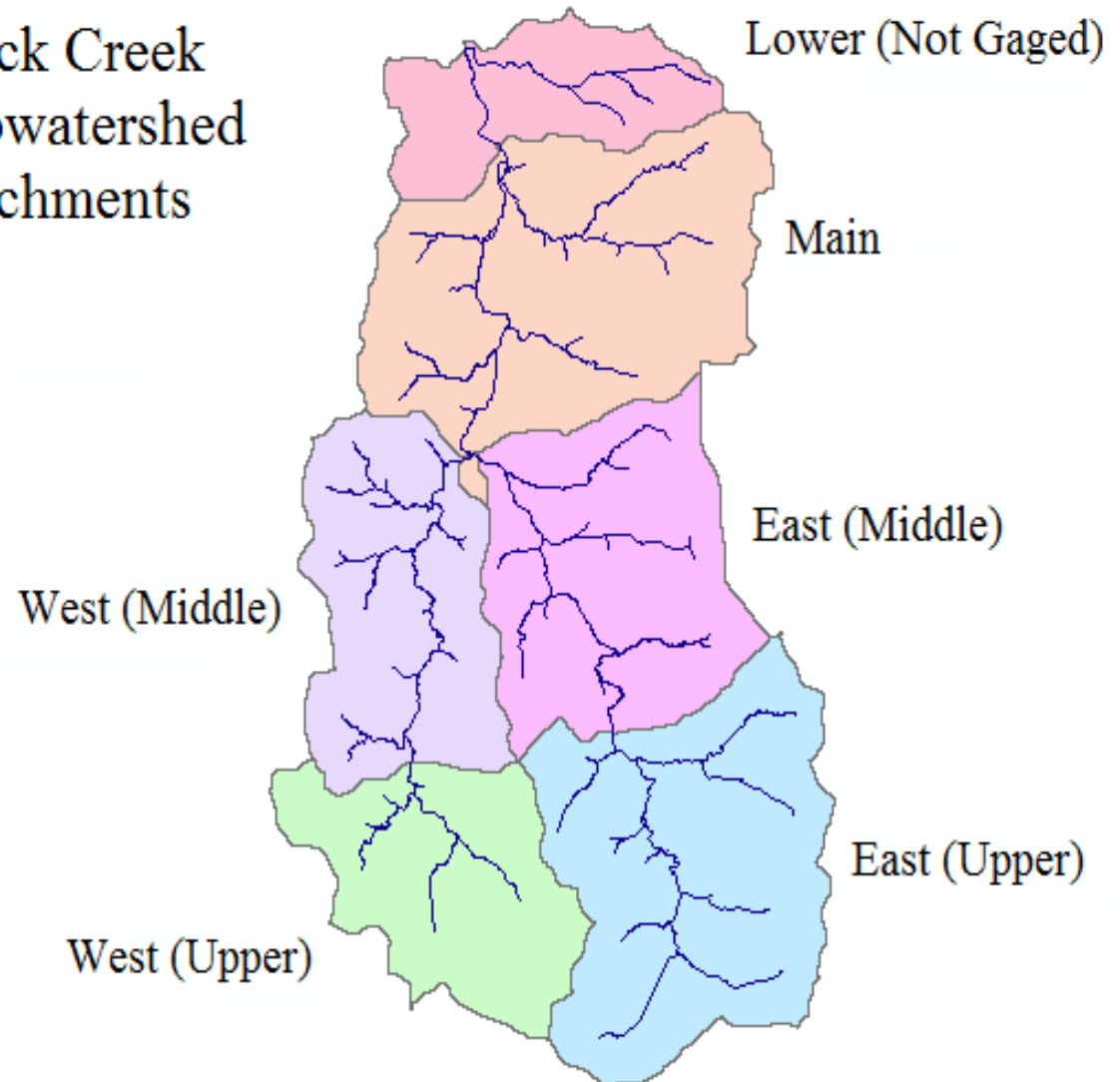
## Objective 3: Identify and prioritize restoration areas

- Zoom in (within the one subwatershed)
- Prioritizing stormwater infrastructure, riparian corridor, and drainage

# Objective 1.1 – Determine Subwatersheds

For demonstration purposes, the Black Creek subwatershed was used, resulting in catchments

Black Creek  
Subwatershed  
Catchments



# Objective 1.2 – Establish Delineation Point

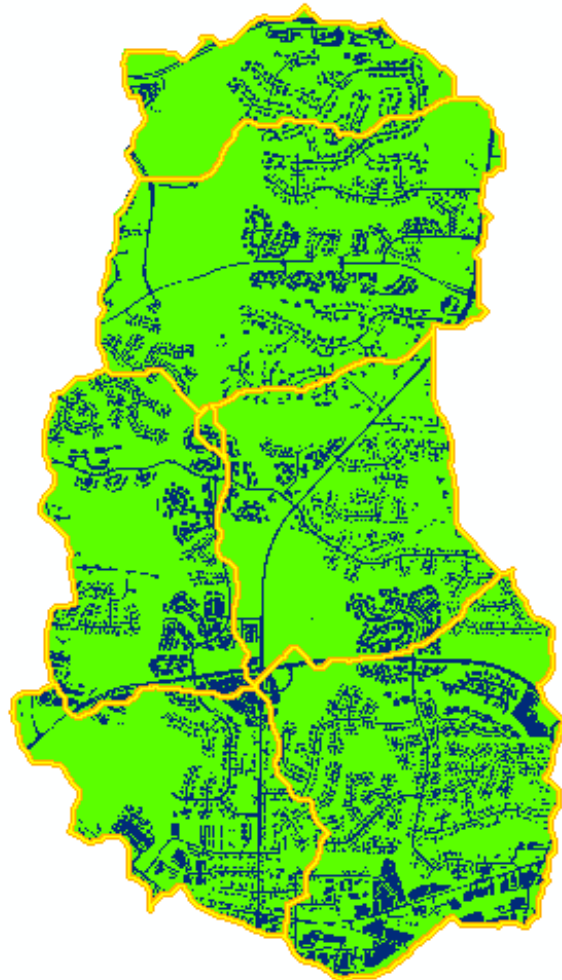
## Applicable Major Regulations

- Neuse River Basin Rules (1998)
- Clean Water Act, Phase II (2003)

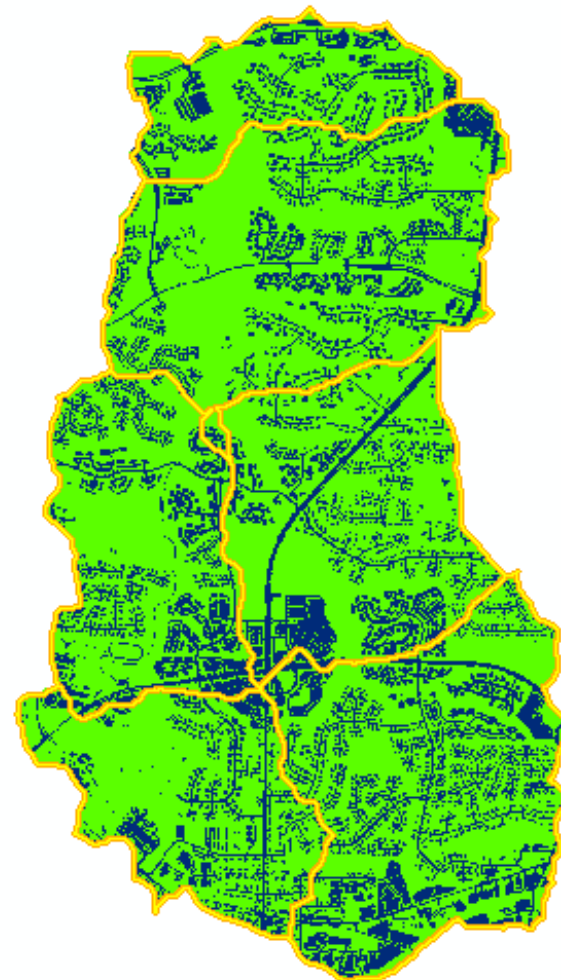
## Results

- The majority of stormwater practices changed with the Neuse River Basin Rules, so 1998 was established as the delineation point between legacy and current stormwater practices

# Objective 1.3 – Collect or Create Impervious Cover Data Sets



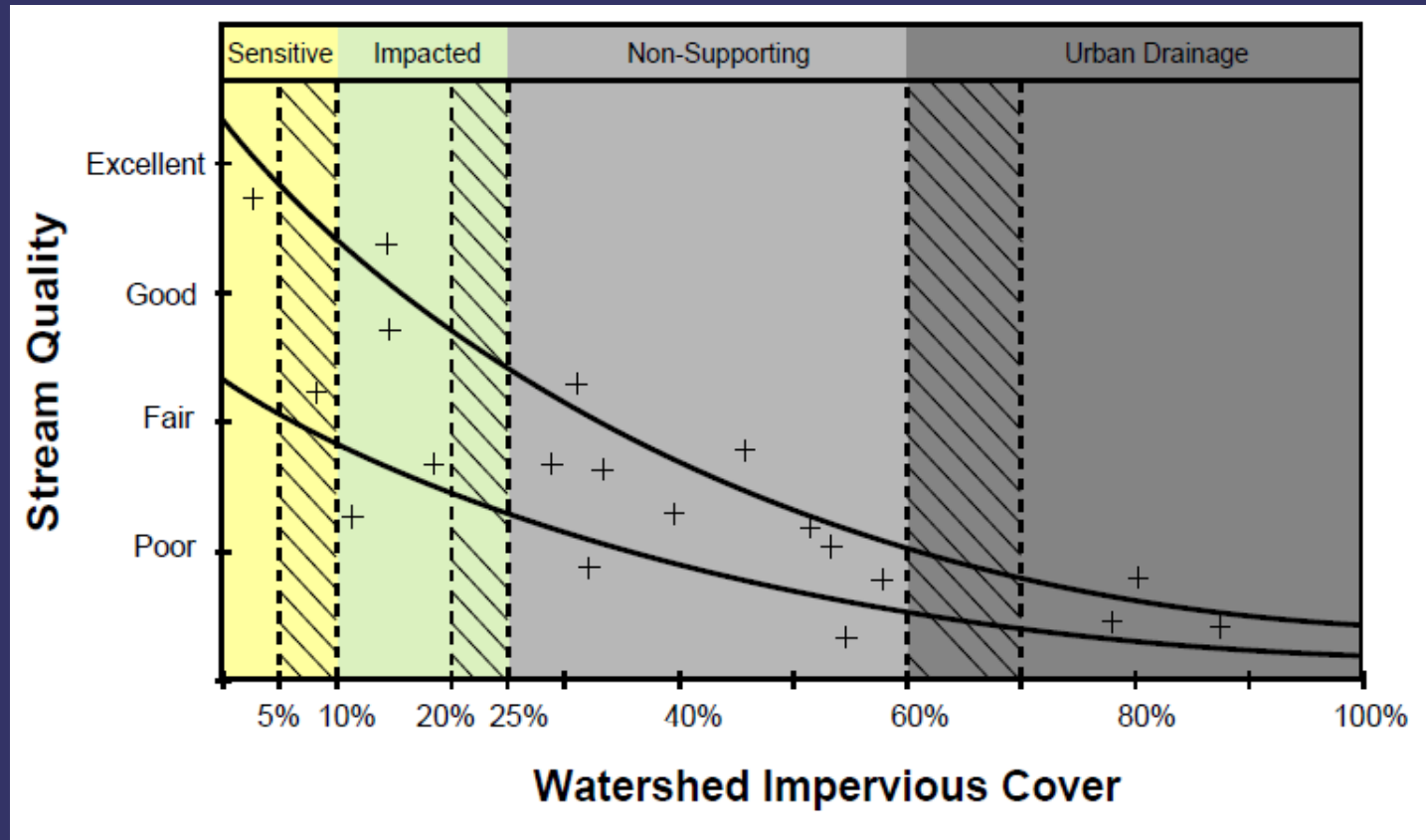
**Priority**  
**Legacy Impervious Surfaces - 1999**



**Additional Consideration**  
**Current Impervious Surfaces - 2010**

Black Creek Flow

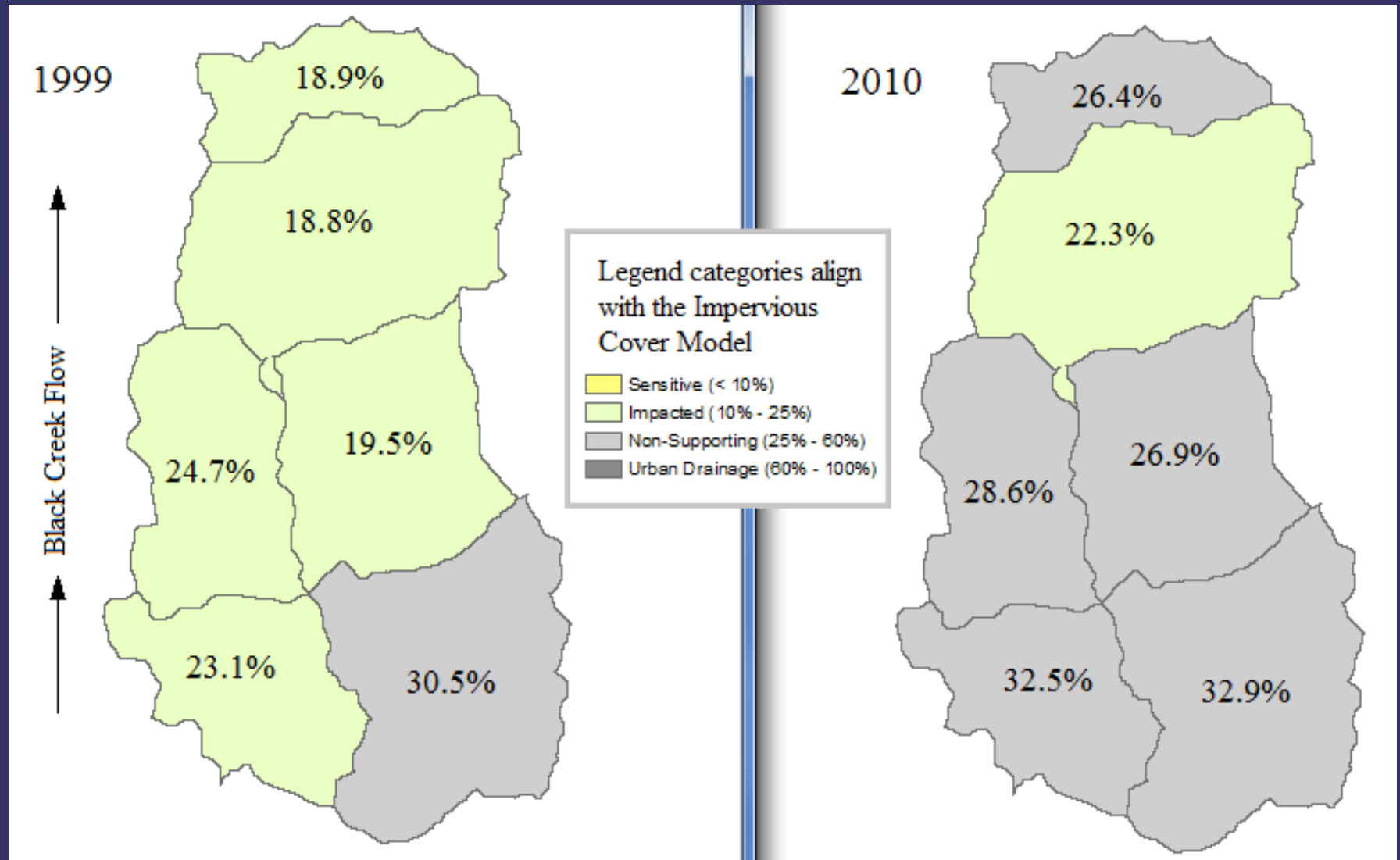
# Objective 1.4 – Prioritize Impervious Cover



The Impervious Cover Model (ICM) provides a valuable generalization of the relationship between impervious cover levels and stream health.



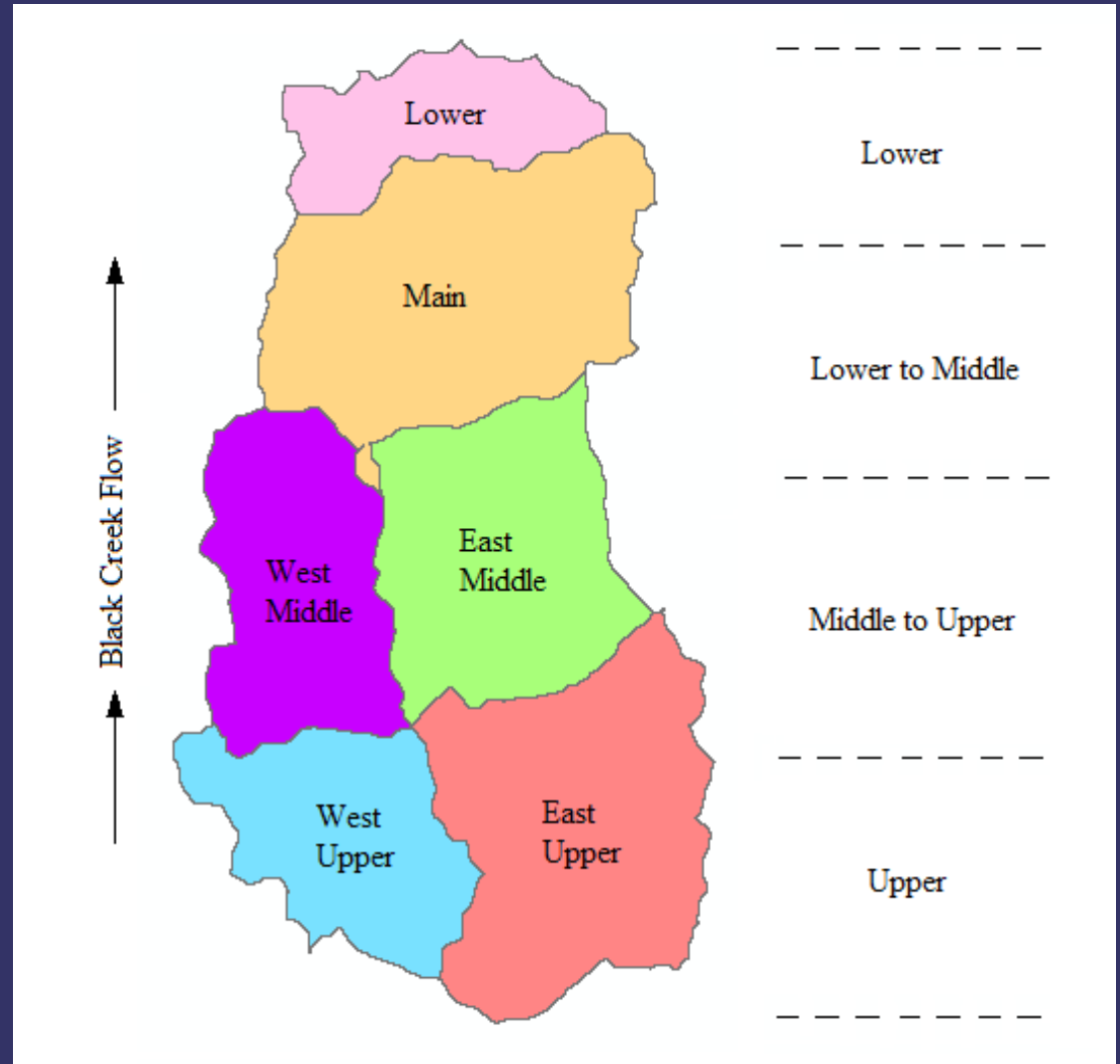
# Objective 1.4 – Prioritize Impervious Cover



# Objective 1.5 – Prioritize Location

## Subwatershed Location

- Efforts in upper subwatersheds benefit lower subwatersheds as well



# Objective 1.6 – Prioritize Subwatersheds

## Combined Prioritization Results

Points (Categories)	Legacy (1999) Impervious Surface Percentage					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
0 (Sensitive (<10%))						
5 (Impacted (10-25%))		23%	20%		19%	19%
10 (Non-Supporting (25-60%))	31%			25%		
15 (Urban Drainage (60-100%))						
Legacy/1999 Point Subtotal	10	5	5	10	5	5
Adjustment for Current/2010 *	0	1	1	1	0	1
<b>Impervious Surface Subtotal</b>	<b>10</b>	<b>6</b>	<b>6</b>	<b>11</b>	<b>5</b>	<b>6</b>

\* Adjustment for Current/2010 – Though legacy development is weighted more heavily for prioritization, current development also has an impact. One point was added to the subtotal if the impervious cover percentage in 2010 resulted in an ICM category shift upward (i.e., from Impacted to Non-Supporting)

Points (Categories)	Catchment Location					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
0 (Lower)						X
5 (Lower to Middle)					X	
10 (Middle to Upper)			X	X		
15 (Upper)	X	X				
<b>Catchment Location Subtotal</b>	<b>15</b>	<b>15</b>	<b>10</b>	<b>10</b>	<b>5</b>	<b>0</b>

	Overall Catchment Prioritization					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
Impervious Surface Subtotal	10	6	6	11	5	6
Catchment Location Subtotal	15	15	10	10	5	0
Point Totals	25	21	16	21	10	6
<b>Priority</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>5</b>

# Objective 2 – Develop Stormwater Goal

Step		Black Creek (acres)
1	Total Subwatershed Area	2217.89
2	Legacy Impervious Cover	508.86
3	Ideal Max Impervious Cover (11% * Step 1) <sup>1</sup>	243.97
4	Disconnection Target (Step 2 – Step 3)	264.89

Ideal Max Impervious Cover <sup>1</sup> - As determined by the ICM and a 1% margin of error

		Existing Retrofits
5	Legacy Disconnections <sup>2</sup>	12.01
6	Revised Disconnection Target (Step 4 – Step 5)	252.88

Legacy Disconnections <sup>2</sup> - As determined through the BMP database kept by the Town of Cary

# Objective 3.1 – Identify Watershed Goal

The Center for Watershed Protection identifies several high level subwatershed restoration goals such as

- Water quality
- Biology
- Physical / hydrology
- Community usage

# Objective 3.2 – Prioritize Catchments

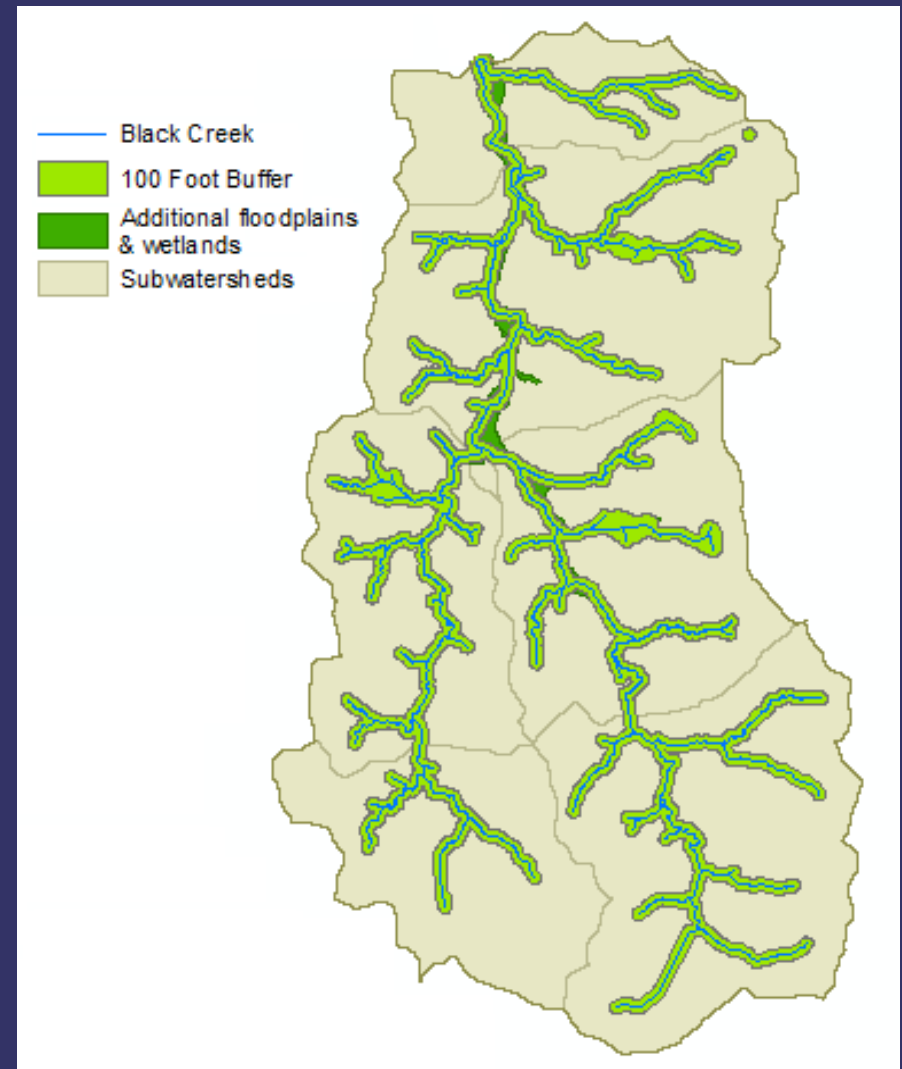
## Collect and Create Data

- Existing Black Creek Watershed Association data
  - Hydrology
  - Land Use & Land Cover
  - Municipal
  - Research
  - Stormwater System
- New project data
  - Subwatershed catchments
  - Impervious surfaces (1999 and 2010)
  - Impervious surface percentages per catchment

# Objective 3.2 – Prioritize Catchments

## Collect and Create Data





- Simplified Variable-Width Riparian Buffer
  - 100 foot regulated
  - Extended to the edge of the floodplain
  - Plus adjacent wetlands

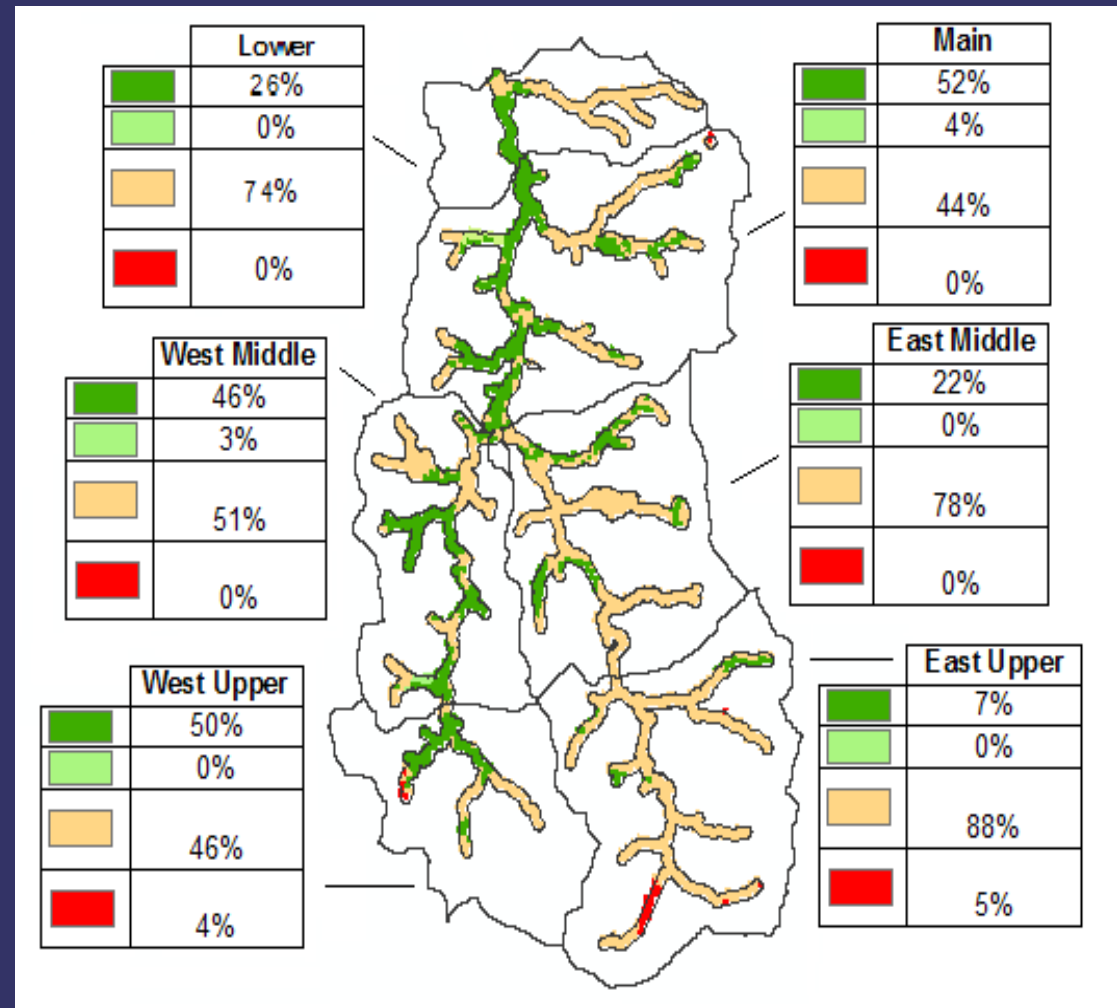


# Objective 3.2 – Prioritize Catchments

## Collect and Create Data

- State of Riparian Corridor
  - Simplified Variable-Width Buffer
  - National Land Cover Data from 2006

	0 (Forest/Woody Wetlands)
	5 (Grassland/Herbaceous)
	10 (Open Space / Low Intensity Development)
	15 (Medium / High Intensity Development)

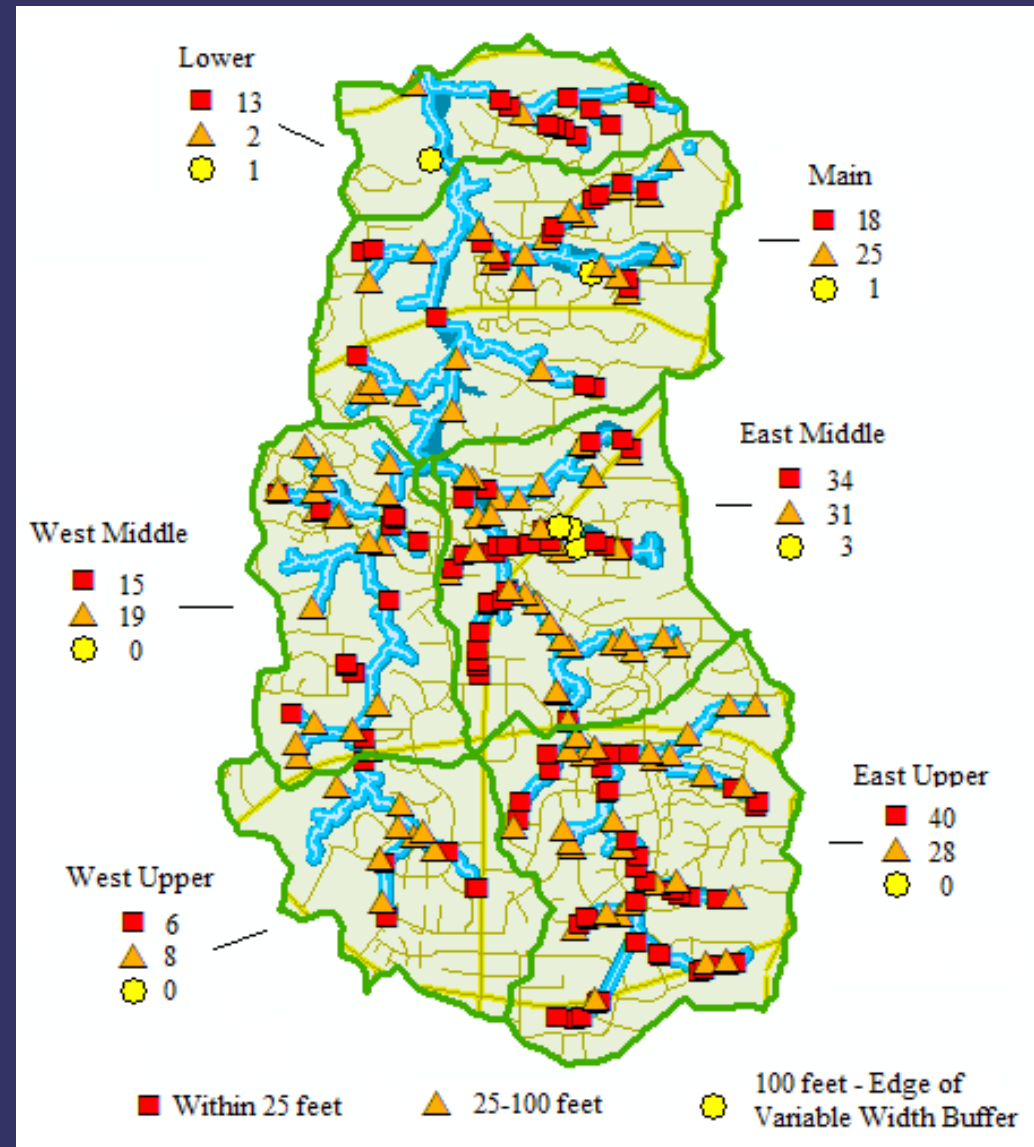




# Objective 3.2 – Prioritize Catchments

## Collect and Create Data

- Outfalls within the Variable-Width Riparian Buffer
- For further evaluation, the outfalls (176) were broken out by
  - 25 feet
  - 100 feet (regulated)
  - Remaining variable width riparian buffer



# Objective 3.2 – Prioritize Catchments

## Catchment Prioritization Summary

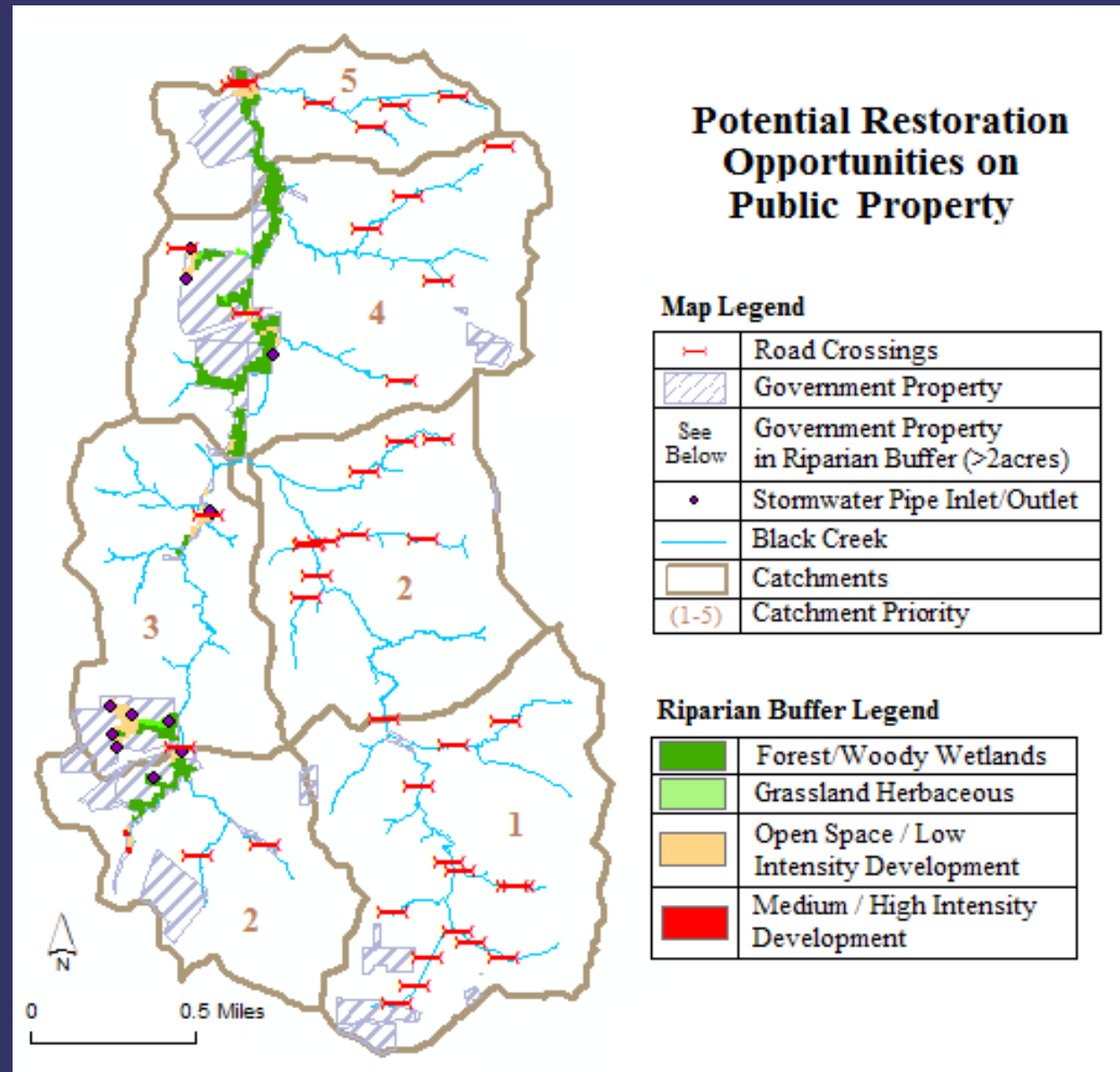
Categories	Overall Catchment Prioritization					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
<b>Catchment Location</b>	15	15	10	10	5	0
<b>Impervious Surfaces</b>	10	6	6	6	5	6
<b>Riparian Corridor*</b>	9.5	5.1	7.8	5.1	4.4	7.4
<b>Stormwater Outfalls**</b>	14.9	12.1	14.3	13.2	12.9	13.8
<b>Gaged Catchment***</b>	1.0	1.0	1.0	1.0	1.0	0.0
<b>Point Total</b>	50.4	39.2	39.1	35.3	28.3	27.2
<b>Priority</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>

Riparian Corridor\* - Weighted average of Land Cover within the variable-width riparian buffer

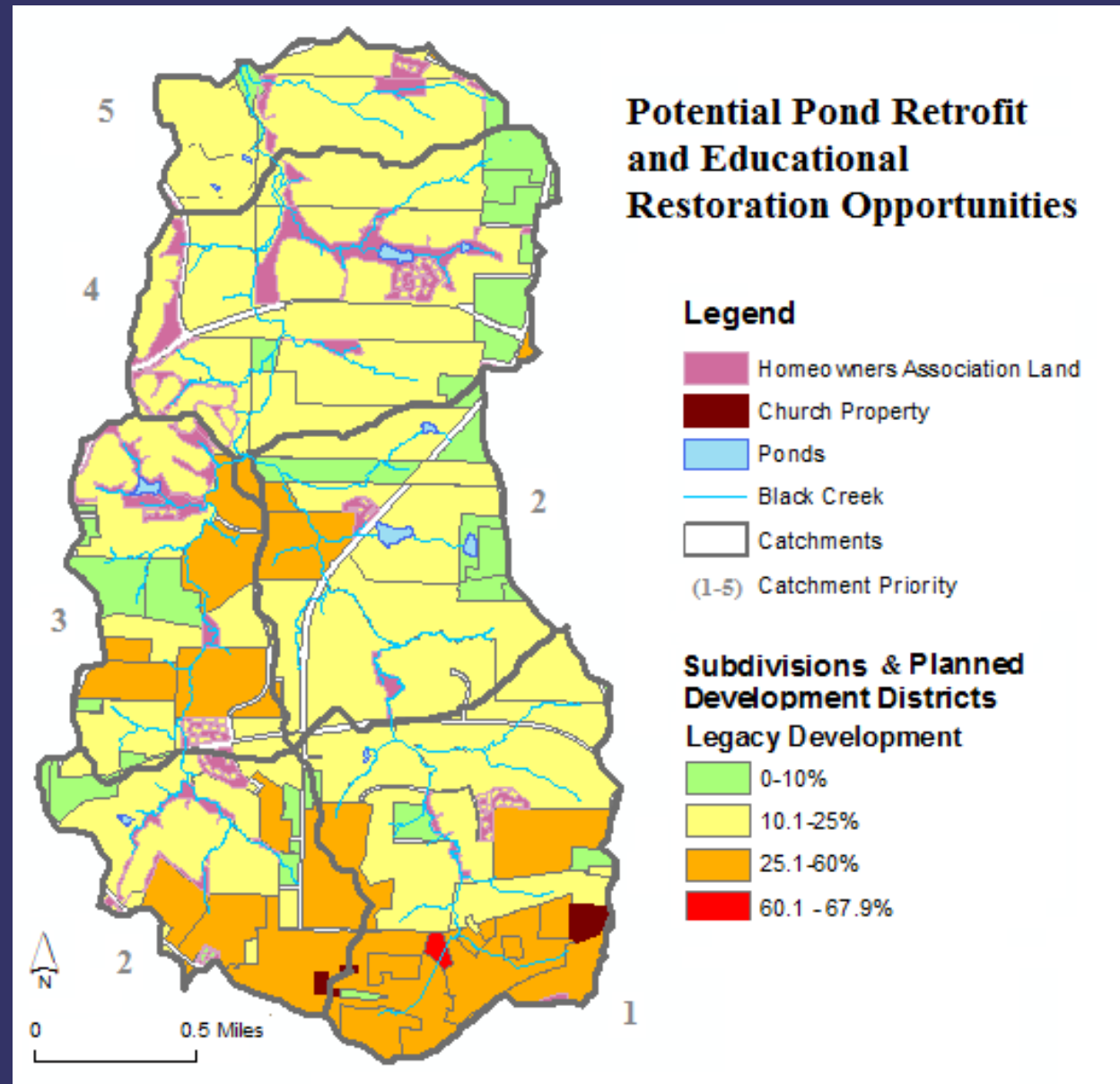
Stormwater Outfalls\*\* - Weighted average per buffer ring, plus an additional priority point per 10% total outfalls

Gaged Catchment\*\*\* - BCWA has a stream gage located in the main catchment. Monitored catchments have been given an additional point in priority

# Objective 3.3 – Identify Restoration Areas



# Objective 3.3 – Identify Restoration Areas



# Conclusion

## Next Steps

- Visit sites
- Determine feasibility and locations
- Calculate disconnection acreage
- Prioritize by drainage, catchment priority, participant interest, and cost

## Review

- Prioritize Subwatersheds – Useful for identifying “target rich” areas
- Set Goal – Useful for many “typical” suburban subwatersheds
- Identify Restoration Sites – Useful for maximizing benefits received for efforts made, but largely individualized

# Acknowledgements

## Concept References

- Effective Impervious Cover, Impervious Cover TMDLs:  
Black Creek Watershed Assoc ([ces.ncsu.edu/weco/blackcreek](http://ces.ncsu.edu/weco/blackcreek))  
Center for Land Use Education & Research ([clear.uconn.edu](http://clear.uconn.edu))  
Nonpoint Education for Municipal Officials ([nemo.uconn.edu](http://nemo.uconn.edu))
- Urban Subwatershed Restoration:  
Center for Watershed Protection ([cwp.org](http://cwp.org))
- Riparian Corridor Study: Seth Wenger ([rivercenter.uga.edu](http://rivercenter.uga.edu))
- Black Creek Watershed Association:  
([ces.ncsu.edu/depts/agecon/WECO/blackcreek/](http://ces.ncsu.edu/depts/agecon/WECO/blackcreek/))

Thanks to Dr. Joseph Bishop (PSU), Dr. Douglas Miller (PSU), Beth F. King (PSU), Christy Perrin (BCWA), Patrick Beggs (BCWA), Amin Davis (BCWA), Charles Brown (Town of Cary)

# Comments or Questions?

[ekhorvath@gmail.com](mailto:ekhorvath@gmail.com)

# Using GIS for Prioritization in Subwatershed Restoration

Elena Horvath  
Advisor: Joseph Bishop, PhD

November 10, 2011

The Pennsylvania State University  
Master in Geographic Information Systems  
[www.gis.psu.edu](http://www.gis.psu.edu)

(Note: Slides 24 – 46 include presentation notes)

1

Presented at the American Water Resources  
Association conference in Albuquerque, NM, on  
November 10, 2011



*Introduction*      Objectives      Methodology and Results      Conclusion

## Project Focus

Geographic Information Systems (GIS)

- How the technical strengths of GIS can prioritize and maximize watershed restoration efforts

Black Creek – Cary, NC

- “Typical” suburban subwatershed
  - 3.3 square miles
  - Largely built out
  - On 303(d) Impaired Waters List
  - Black Creek Watershed Association (BCWA)
  - Primary indicator – stormwater runoff

2

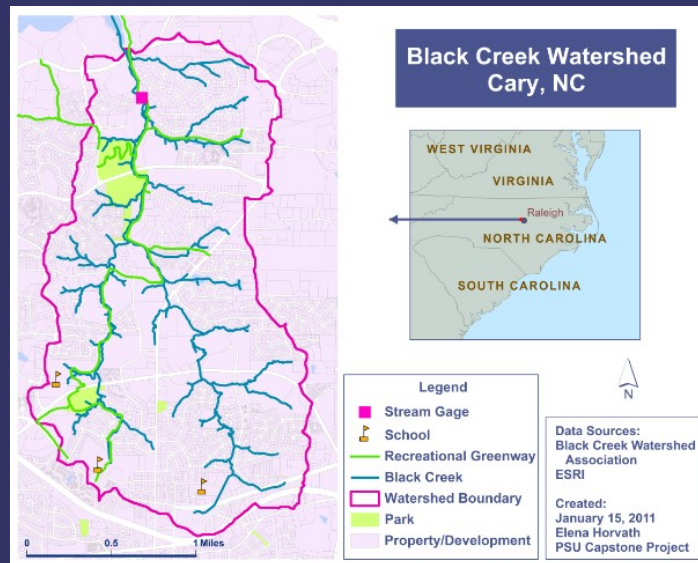
### GIS:

- GIS can be used throughout the subwatershed restoration process → mapping, analysis, tracking, communication, and education
- Funding is limited. GIS can help prioritize and maximize watershed management efforts.

### Black Creek & Black Creek Watershed Association

- BC Development: Largely built out with legacy stormwater infrastructure (collect & funnel stormwater downstream as quickly & efficiently as possible to minimize local flooding)
- BCWA Efforts to date: Watershed health assessment, plan, educational presentations, hands-on volunteer projects, bioretention retrofits at local school
- BCWA/NCSU Watershed Assessment: Indicates that a high volume and accumulation of toxic organic chemicals associated with a high percentage of impervious surfaces and subsequent runoff have degraded the water quality
- BCWA Goals: Stream health restoration, education; Measurable progress by 2014, removal from 303(d) list by 2018

## Study Area



Again, “typical” to many suburban subwatersheds → several subdivisions, a few schools, a few parks, and a recreational greenway/path for jogging, biking, etc.

The indicated stream gage was installed by the BCWA.

## Objective Overview

### Objective 1: Prioritize subwatersheds

- Zoom out (multiple subwatersheds)
- Evaluate impervious cover
- Prioritizing legacy “target rich” development and location

### Objective 2: Develop the stormwater retrofit goal

- Zoom in (one subwatershed)
- Focus on impervious cover rather than pollutant-specific TMDLs (Eagleville Brook Model)
- Setting a target based on acreage to “disconnect” legacy runoff

### Objective 3: Identify and prioritize restoration areas

- Zoom in (within the one subwatershed)
- Prioritizing stormwater infrastructure, riparian corridor, and drainage

### Objective 1:

- **Level:** Zoom out to multiple subwatersheds, such as with a municipality or river-level watershed
- **Concept:** Impervious cover typically results in degraded water quality & can be used for a general evaluation
- **Alternative Concept:** Can also prioritize legacy development (higher than current development which retains and handles more stormwater onsite) and location within the watershed

### Objective 2:

- **Level:** Once subwatersheds are prioritized, zoom in to one subwatershed
- **Concept:** TMDLs are traditionally pollutant-specific
- **Alternative Concept:** When stormwater is the primary indicator, consider targets based on reducing overall volume by disconnecting runoff (as in Eagleville Brook) and prioritizing legacy stormwater infrastructure

### Objective 3:

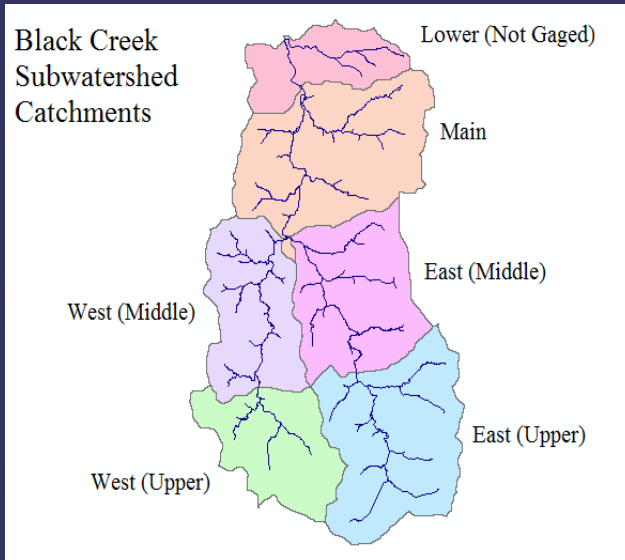
**Level:** Once the target is set, zoom in to within the subwatershed

**Concept:** Search for retrofit opportunities

**Alternative Concept:** Prioritize based on “target rich” legacy stormwater infrastructure, the state of a variable-width riparian corridor, and the drainage acreage that would be disconnected

## Objective 1.1 – Determine Subwatersheds

For demonstration purposes, the Black Creek subwatershed was used, resulting in catchments



So zooming back out, the first objective was to prioritize subwatersheds within, e.g., a municipality or river-level watershed

The first step then was to determine the subwatershed boundaries

Though it is a single subwatershed, the Black Creek subwatershed was used for demonstration purposes.

## Objective 1.2 – Establish Delineation Point

### Applicable Major Regulations

- Neuse River Basin Rules (1998)
- Clean Water Act, Phase II (2003)

### Results

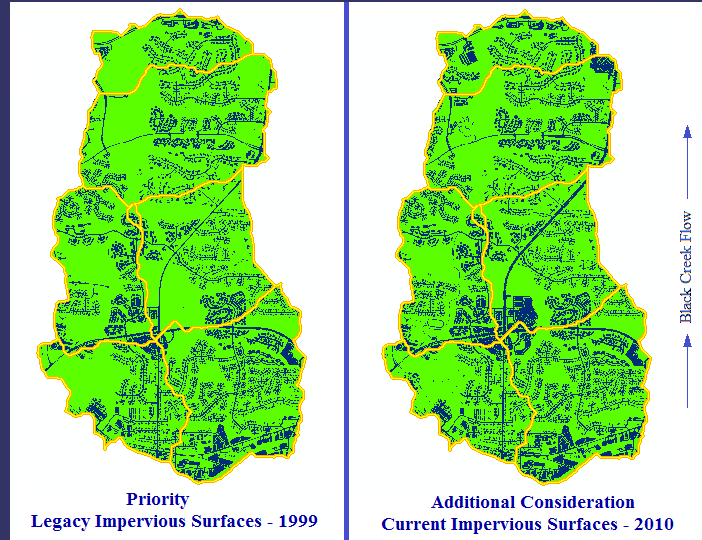
- The majority of stormwater practices changed with the Neuse River Basin Rules, so 1998 was established as the delineation point between legacy and current stormwater practices

The second step in prioritizing subwatersheds was to establish a delineation point between legacy (funnel downstream) and current (retain more onsite) stormwater practices in the regulations

- Black Creek is primarily regulated by two sets of regulations
- Black Creek is located within the Neuse River basin. The Neuse River Basin Rules were established in response to pfiesteria outbreaks and the resulting fish kills in the 1990s.
  - Black Creek is also located wholly within the Town of Cary, a Phase II municipality as defined by the Clean Water Act.

The majority of stormwater practices changed with the Neuse River Basin Rules, so 1998 was designated as the delineation point between legacy and current stormwater practices.

## Objective 1.3 – Collect or Create Impervious Cover Data Sets



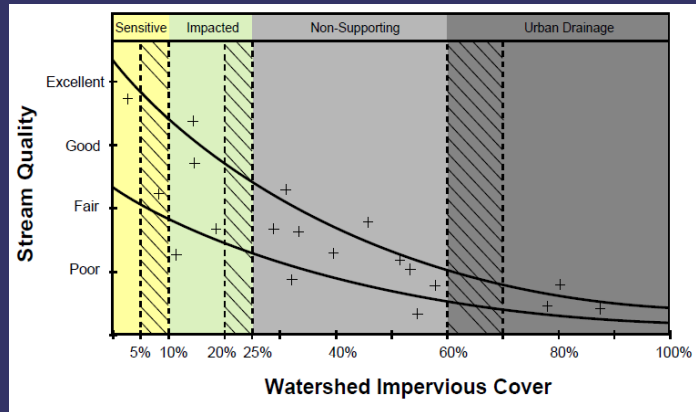
7

The third step in prioritizing subwatersheds was to collect and create impervious cover data sets.

The Town of Cary shared an impervious cover analysis contracted out and completed in 1999. This became the Legacy Impervious Surfaces layer.

Using publicly-available 2010 orthophotography for Wake County, newer developments were hand-digitized in ArcGIS to create the Current Impervious Surfaces layer.

## Objective 1.4 – Prioritize Impervious Cover



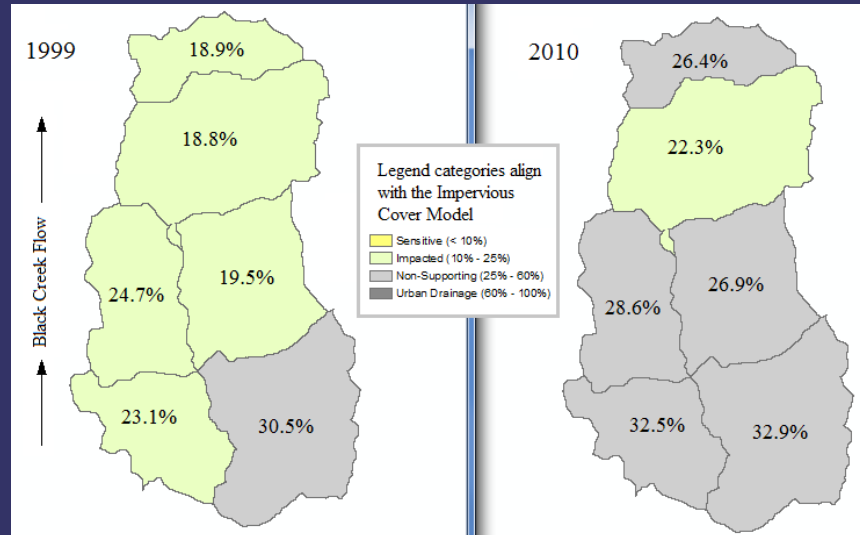
The Impervious Cover Model (ICM) provides a valuable generalization of the relationship between impervious cover levels and stream health.

Impervious Cover Model - Schueler, T. L., Fraley-McNeal, and K. Cappiella. 2009 Mar/Apr. Is Impervious Cover Still Important? Review of Recent Research. Journal of Hydrologic Engineering. 14(4): 309-315. <http://cedb.asce.org/cgi/WWWdisplay.cgi?170460>

The fourth step in prioritizing subwatersheds was to prioritize based on impervious cover.

The Impervious Cover Model provides a valuable generalization of the relationship between impervious cover levels and stream health.

## Objective 1.4 – Prioritize Impervious Cover



In this slide, the legacy and current impervious surface layers were categorized according to the Impervious Cover Model.

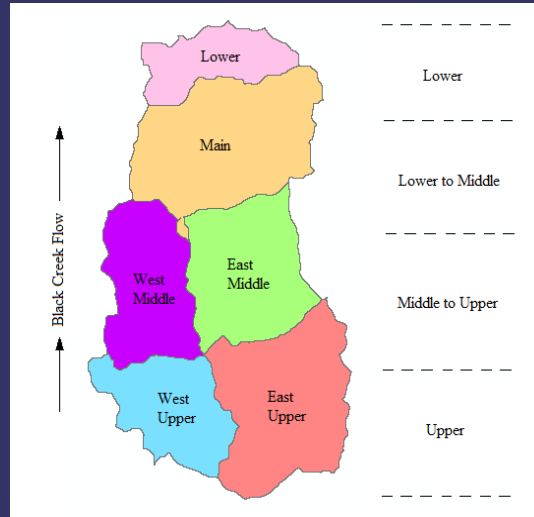
Though legacy development will be prioritized because it is “target rich” (and should result in greater benefits if retrofitted), current development does impact the subwatershed and is, therefore, also considered in the prioritization.



## Objective 1.5 – Prioritize Location

### Subwatershed Location

- Efforts in upper subwatersheds benefit lower subwatersheds as well



The fifth step in prioritizing subwatersheds was to prioritize by location.

Restoration efforts in upper subwatersheds (catchments) benefit lower subwatersheds as well.

## Objective 1.6 – Prioritize Subwatersheds

### Combined Prioritization Results

Points (Categories)	Legacy (1999) Impervious Surface Percentage					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
0 (Sensitive (<10%))						
5 (Impacted (10-25%))		23%	20%		19%	19%
10 (Non-Supporting (25-60%))	31%			25%		
15 (Urban Drainage (60-100%))						
Legacy/1999 Point Subtotal	10	5	5	10	5	5
Adjustment for Current/2010 *	0	1	1	1	0	1
<b>Impervious Surface Subtotal</b>	<b>10</b>	<b>6</b>	<b>6</b>	<b>11</b>	<b>5</b>	<b>6</b>

\* Adjustment for Current/2010 – Though legacy development is weighted more heavily for prioritization, current development also has an impact. One point was added to the subtotal if the impervious cover percentage in 2010 resulted in an ICM category shift upward (i.e., from Impacted to Non-Supporting)

Points (Categories)	Catchment Location					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
0 (Lower)						X
5 (Lower to Middle)					X	
10 (Middle to Upper)			X	X		
15 (Upper)	X	X				
<b>Catchment Location Subtotal</b>	<b>15</b>	<b>15</b>	<b>10</b>	<b>10</b>	<b>5</b>	<b>0</b>

Overall Catchment Prioritization						
Impervious Surface Subtotal	10	6	6	11	5	6
Catchment Location Subtotal	15	15	10	10	5	0
Point Totals	25	21	16	21	10	6
<b>Priority</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>5</b>

11

And the final step in prioritizing subwatersheds was to compile the results.

Legacy impervious surface percentages were categorized and prioritized based on the Impervious Cover Model.

Additional points were given to account for continued growth in the subwatershed (catchment).

Subwatersheds (catchments) were then categorized and prioritized based on their location within the watershed (subwatershed).

All results were then compiled for an overall subwatershed (catchment) prioritization.

## Objective 2 – Develop Stormwater Goal

Step		Black Creek (acres)
1	Total Subwatershed Area	2217.89
2	Legacy Impervious Cover	508.86
3	Ideal Max Impervious Cover (11% * Step 1) <sup>1</sup>	243.97
4	Disconnection Target (Step 2 – Step 3)	264.89
Ideal Max Impervious Cover <sup>1</sup> - As determined by the ICM and a 1% margin of error		
		<b>Existing Retrofits</b>
5	Legacy Disconnections <sup>2</sup>	12.01
6	Revised Disconnection Target (Step 4 – Step 5)	252.88
Legacy Disconnections <sup>2</sup> - As determined through the BMP database kept by the Town of Cary		

12

Once the subwatersheds have been prioritized, restoration focus can be zoomed to a single subwatershed, such as Black Creek.

When stormwater is the primary indicator, targets based on reducing/disconnecting runoff (as was done with Eagleville Brook, CT) & prioritizing legacy development may be more effective than traditional pollutant-specific TMDLs.

Using ArcGIS, the subwatershed area (acres) and legacy impervious cover (acres) were calculated.

Next, an ideal maximum impervious cover percentage was established based on the ICM and a 1% margin of error.

This ideal maximum impervious cover percentage was converted to acres and subtracted from the actual legacy impervious cover, resulting in the disconnection target.

The Town of Cary maintains a Best Management Practices (BMP) database. The drainage areas associated with BMPs in legacy development were subtracted for a revised target.

## Objective 3.1 – Identify Watershed Goal

The Center for Watershed Protection identifies several high level subwatershed restoration goals such as

- Water quality
- Biology
- Physical / hydrology
- Community usage

Once the retrofit target is set, restoration focus can be zoomed in to within the subwatershed. Potential retrofit opportunities can be prioritized based on “target rich” legacy development, the state of a variable-width riparian corridor, and the drainage acreage that would be disconnected. The first step in prioritizing restoration areas is to identify the high level subwatershed goal. If the goals include the restoration of certain species, specific habitat requirements may need to be required.

In the case of Black Creek, the focus is on the generalized restoration of the stream's aquatic health and the associated recreational benefits.

## Objective 3.2 – Prioritize Catchments

### Collect and Create Data

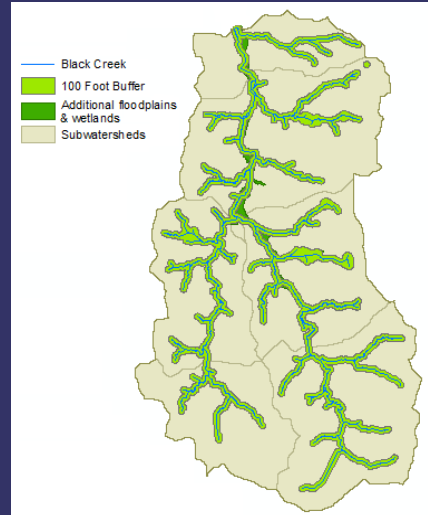
- Existing Black Creek Watershed Association data
  - Hydrology
  - Land Use & Land Cover
  - Municipal
  - Research
  - Stormwater System
- New project data
  - Subwatershed catchments
  - Impervious surfaces (1999 and 2010)
  - Impervious surface percentages per catchment

The second step in prioritizing restoration areas is to prioritize catchments. Several data sets had already been collected and created for this project.

## Objective 3.2 – Prioritize Catchments

### Collect and Create Data

- Simplified Variable-Width Riparian Buffer
  - 100 foot regulated
  - Extended to the edge of the floodplain
  - Plus adjacent wetlands



15

To help quantify factors for prioritization, a simplified variable-width riparian buffer was created using ArcGIS.

First, the stream was buffered by 100 feet.

Next, the buffer was extended to the edge of the floodplain.

Finally, the buffer was extended to any adjacent wetlands.

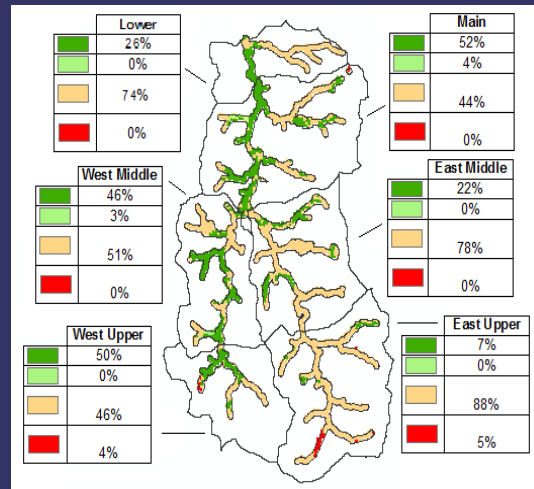
Other variable parameters, such as soil type, will vary in relevance, depending on where the subwatershed is located.

## Objective 3.2 – Prioritize Catchments

### Collect and Create Data

- State of Riparian Corridor
  - Simplified Variable-Width Buffer
  - National Land Cover Data from 2006

	0 (Forest/Woody Wetlands)
	5 (Grassland/Herbaceous)
	10 (Open Space / Low Intensity Development)
	15 (Medium / High Intensity Development)



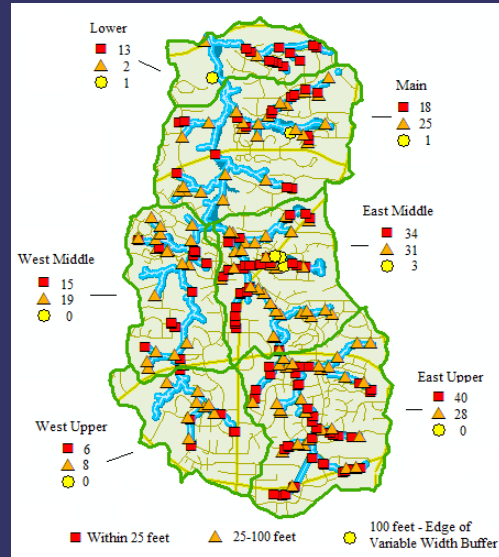
16

The state of the variable-width riparian buffer was then categorized using the National Land Cover Data from 2006 and evaluated by catchment.

## Objective 3.2 – Prioritize Catchments

### Collect and Create Data

- Outfalls within the Variable-Width Riparian Buffer
- For further evaluation, the outfalls (176) were broken out by
  - 25 feet
  - 100 feet (regulated)
  - Remaining variable width riparian buffer



176 stormwater outfalls exist within the variable-width riparian buffer, bypassing many of the riparian corridor's benefits.



## Objective 3.2 – Prioritize Catchments

### Catchment Prioritization Summary

Categories	Overall Catchment Prioritization					
	East Upper	West Upper	East Middle	West Middle	Main	Lower
Catchment Location	15	15	10	10	5	0
Impervious Surfaces	10	6	6	6	5	6
Riparian Corridor*	9.5	5.1	7.8	5.1	4.4	7.4
Stormwater Outfalls**	14.9	12.1	14.3	13.2	12.9	13.8
Gaged Catchment***	1.0	1.0	1.0	1.0	1.0	0.0
Point Total	50.4	39.2	39.1	35.3	28.3	27.2
Priority	1	2	2	3	4	5

Riparian Corridor\* - Weighted average of Land Cover within the variable-width riparian buffer

Stormwater Outfalls\*\* - Weighted average per buffer ring, plus an additional priority point per 10% total outfalls

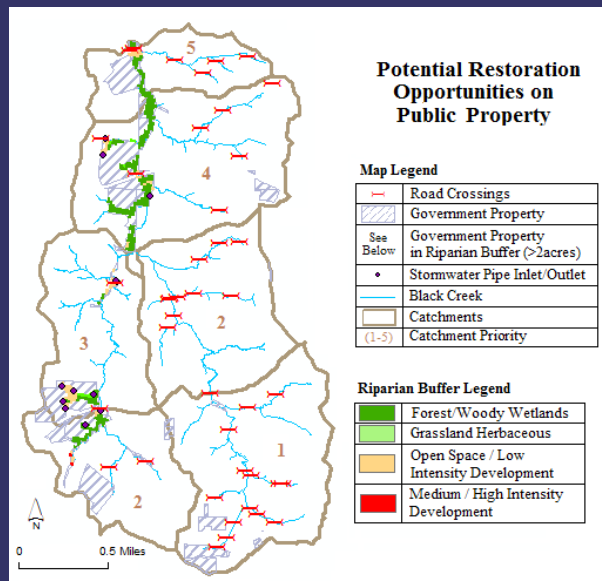
Gaged Catchment\*\*\* - BCWA has a stream gage located in the main catchment. Monitored catchments have been given an additional point in priority

18

The individual results were compiled for an overall catchment prioritization.

- Catchment Location: Upper catchments benefit lower catchments as well. Details were covered previously.
- Impervious Surfaces: Restoration within legacy development is likely to be more beneficial to the subwatershed. Details were covered previously.
- Riparian Corridor: Land cover types were categorized (Forest-0; Grass-5; Open/Low-10; Med/High-15). Then coverage percentages within each catchment were used to create weighted averages.
- Stormwater Outfalls: Outfalls were categorized (25 ft-5; 100 ft-10; VWB-15). The number of outfalls within each catchment was used to create weighted averages. An adjustment was then added per 10% total outfalls (i.e., a catchment with 68 outfalls is a higher priority than a catchment with 14 outfalls).
- Points were summarized.
- Priorities were assigned.

## Objective 3.3 – Identify Restoration Areas



19

The third step in prioritizing restoration areas is to identify potential restoration areas.

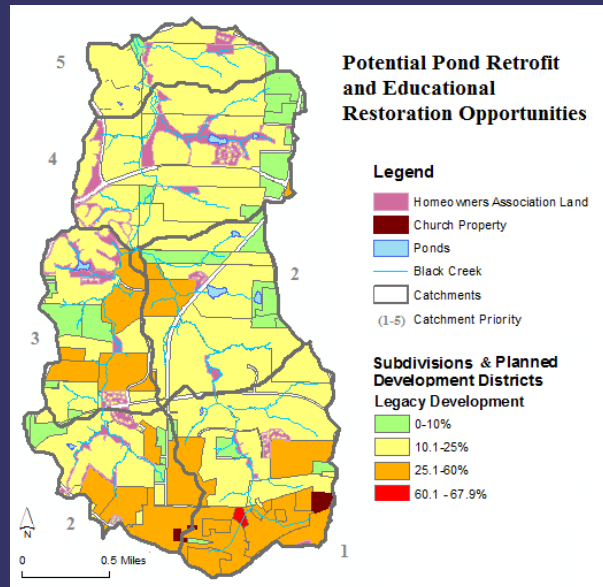
This slide is largely focused on potential opportunities on public property.

First, road crossings were identified. This was done using an intersection between the roads and stream layer, with a point output layer, in ArcGIS.

Second, government property (town, county, and state) was identified. This was done using an ownership attribute/field in the Town of Cary CaryProperty layer.

Third, government property with at least two acres of the variable-width riparian buffer and the associated stormwater outlets were identified. This was done using Select by Location (government prop within the buffer), adding a new field for the area, and Calculat(ing) the Geometry (area in acres).

## Objective 3.3 – Identify Restoration Areas



20

This slide is focused on potential pond retrofit and educational restoration opportunities.

Existing ponds can provide additional stormwater storage retrofit opportunities.

A core goal of Watershed Education of Communities and Officials (WECO), the NC State University cooperative extension that supports and facilitates the Black Creek Watershed Association (BCWA) is education.

Homeowners Associations and churches can provide opportunities to educate the public on steps they can take to improve the subwatershed's health through onsite retrofits. These groups were identified using Cary's ResidentialAndNonResidential layer.

In addition, the percentages of legacy development were calculated for prioritization.

Introduction      Objectives      Methodology and Results      **Conclusion**

# Conclusion

Next Steps

- Visit sites
- Determine feasibility and locations
- Calculate disconnection acreage
- Prioritize by drainage, catchment priority, participant interest, and cost

Review

- Prioritize Subwatersheds – Useful for identifying “target rich” areas
- Set Goal – Useful for many “typical” suburban subwatersheds
- Identify Restoration Sites – Useful for maximizing benefits received for efforts made, but largely individualized

21

**Prioritize Subwatersheds** - Zoom out to watershed or municipality with multiple subwatersheds. Prioritizes based on impervious surfaces (particularly legacy development) and subwatershed location (upper is more advantageous). Useful for identifying “target rich” restoration areas.

**Set Goal** – Zoom in to one subwatershed. Set stormwater “disconnection” goal by subtracting the ideal maximum impervious cover acreage from the actual legacy impervious cover acreage. Useful for many “typical” suburban subwatersheds negatively impacted by legacy stormwater infrastructure.

**Identify Restoration Sites** – Zoom in within the subwatershed. Identified through examining available layers and attributes. Useful for maximizing benefits received for efforts made, but largely individualized based on creativity, asking questions, available data, and local knowledge.

# Acknowledgements

## Concept References

- Effective Impervious Cover, Impervious Cover TMDLs:  
Black Creek Watershed Assoc ([ces.ncsu.edu/weco/blackcreek](http://ces.ncsu.edu/weco/blackcreek))  
Center for Land Use Education & Research ([clear.uconn.edu](http://clear.uconn.edu))  
Nonpoint Education for Municipal Officials ([nemo.uconn.edu](http://nemo.uconn.edu))
- Urban Subwatershed Restoration:  
Center for Watershed Protection ([cwp.org](http://cwp.org))
- Riparian Corridor Study: Seth Wenger ([rivercenter.uga.edu](http://rivercenter.uga.edu))
- Black Creek Watershed Association:  
([ces.ncsu.edu/depts/agecon/WECO/blackcreek/](http://ces.ncsu.edu/depts/agecon/WECO/blackcreek/))

Thanks to Dr. Joseph Bishop (PSU), Dr. Douglas Miller (PSU), Beth F. King (PSU), Christy Perrin (BCWA), Patrick Beggs (BCWA), Amin Davis (BCWA), Charles Brown (Town of Cary)

Several people and organizations have supported various aspects of this project, especially the following:

The Geography Department, the Wold Campus, and Penn State have put together excellent distance-learning GIS certificate and degree programs.

Dr. Joseph Bishop has provided feedback and guidance throughout this final project.

Christy Perrin and the Black Creek Watershed Association provided my introduction to the concept of effective impervious cover, as well as the overall watershed restoration process.

The Center for Watershed Protection provides valuable, comprehensive, downloadable, and largely free guides to subwatershed restoration.

## Comments or Questions?

ekhorvath@gmail.com

23

I am interested in any constructive feedback regarding this project, if any components of this project are used elsewhere as a result of this project, and similar efforts to leverage the strengths of GIS in watershed restoration.  
Thank you for your time.