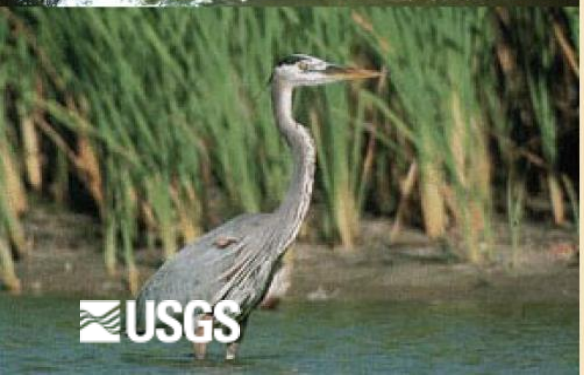


Chesapeake Bay Program
A Watershed Partnership

Phase 6 Land Use Primer

Karl Berger, Chair, Land Use Workgroup
Peter Claggett, Coordinator, Land Use Workgroup

Urban Stormwater Workgroup
May 15, 2017

Local land use and parcel data

- Low-density Residential
- Recreation
- Agriculture
- Roads

High-resolution land cover data

- Impervious surfaces
- Tree canopy
- Low vegetation
- Water

Chesapeake Bay Watershed Land Uses

- Impervious-Roads
- Forests
- Turf Grass
- Open Space

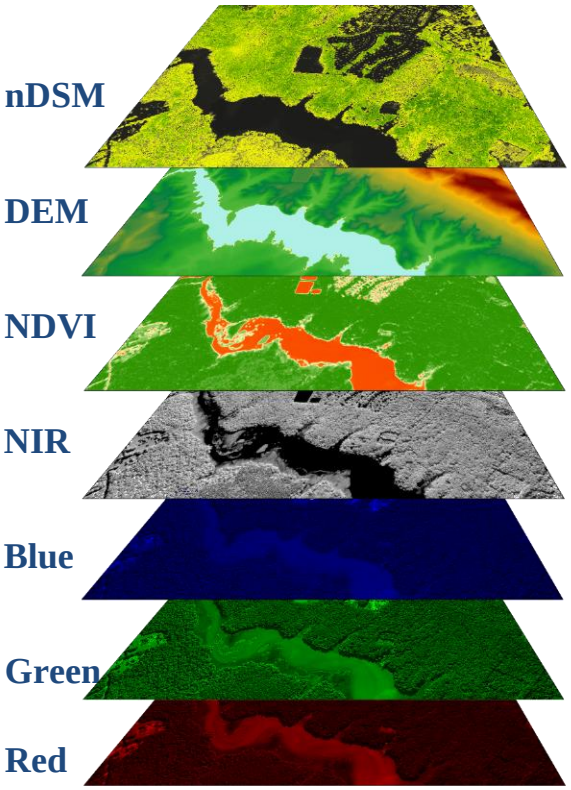
USGS

Remote Sensing Data

2013 NAIP

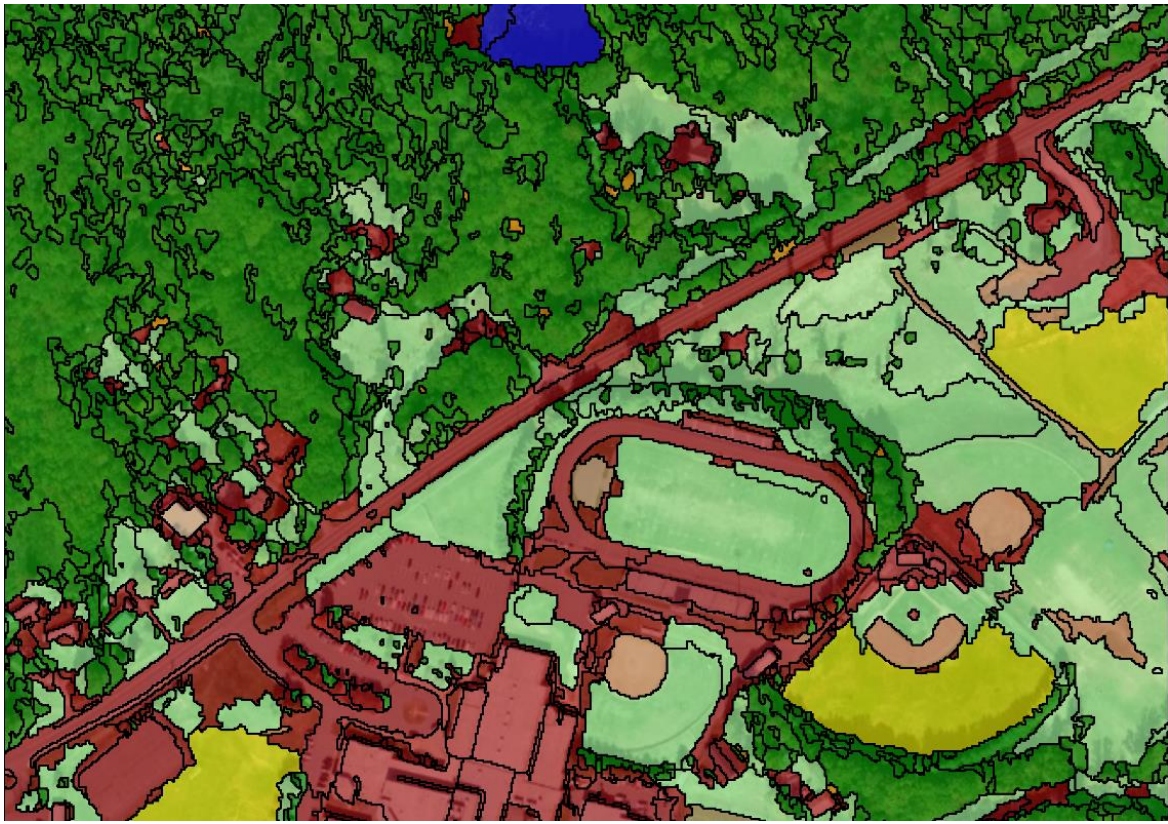
Ortho-imagery

LiDAR



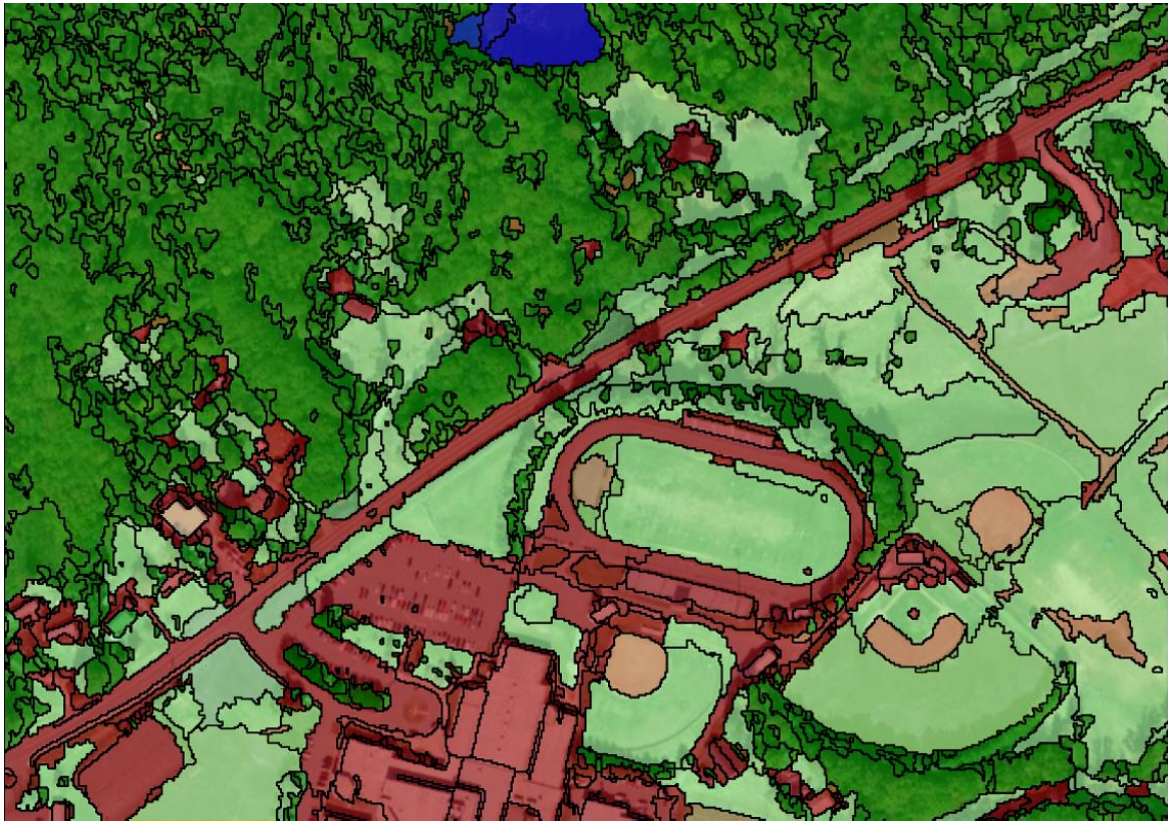
Methods

- **Initial semi-automated feature extraction with 900x the resolution of NLCD**
  - **Rule-based, object oriented image classification**

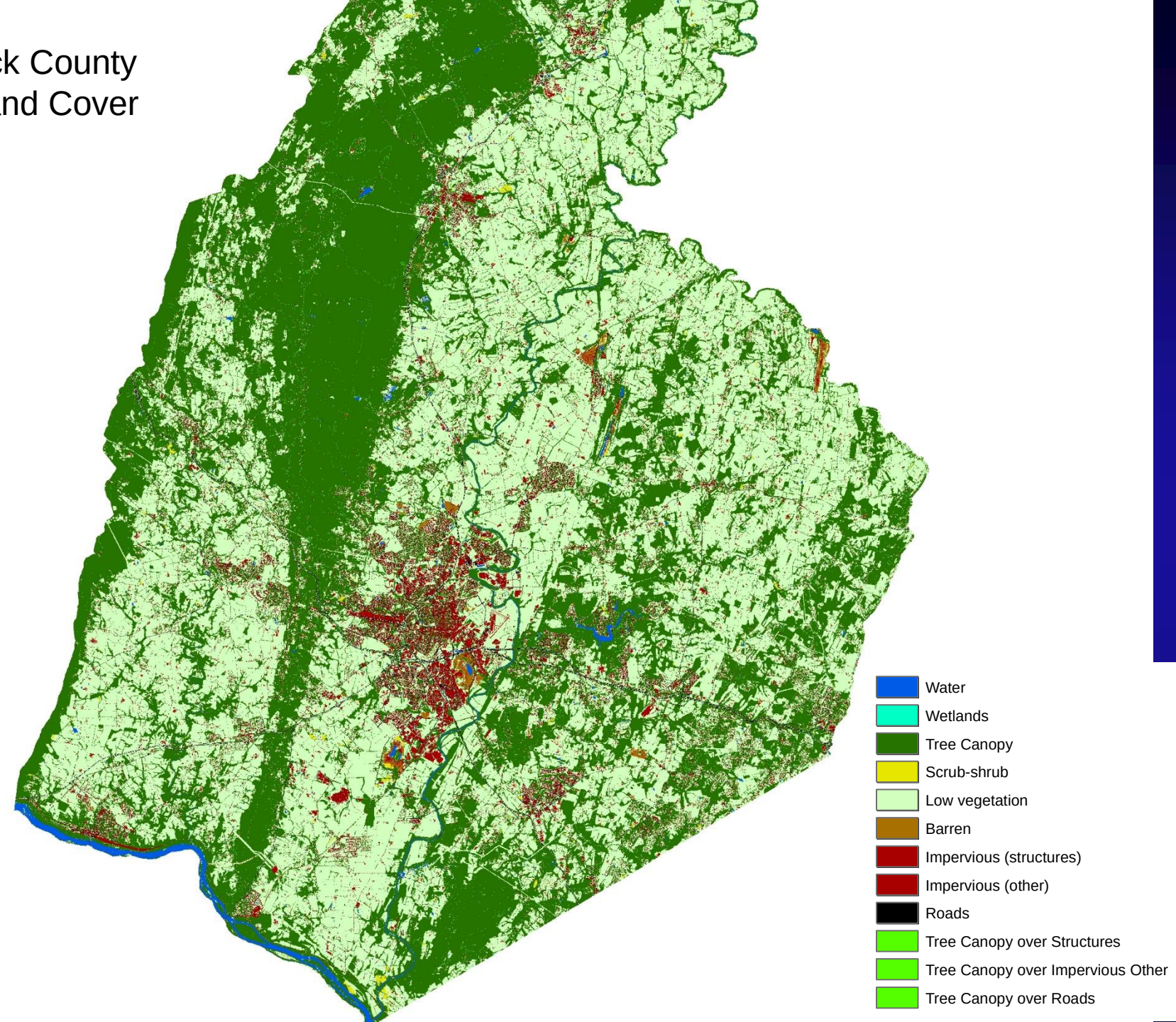


Methods

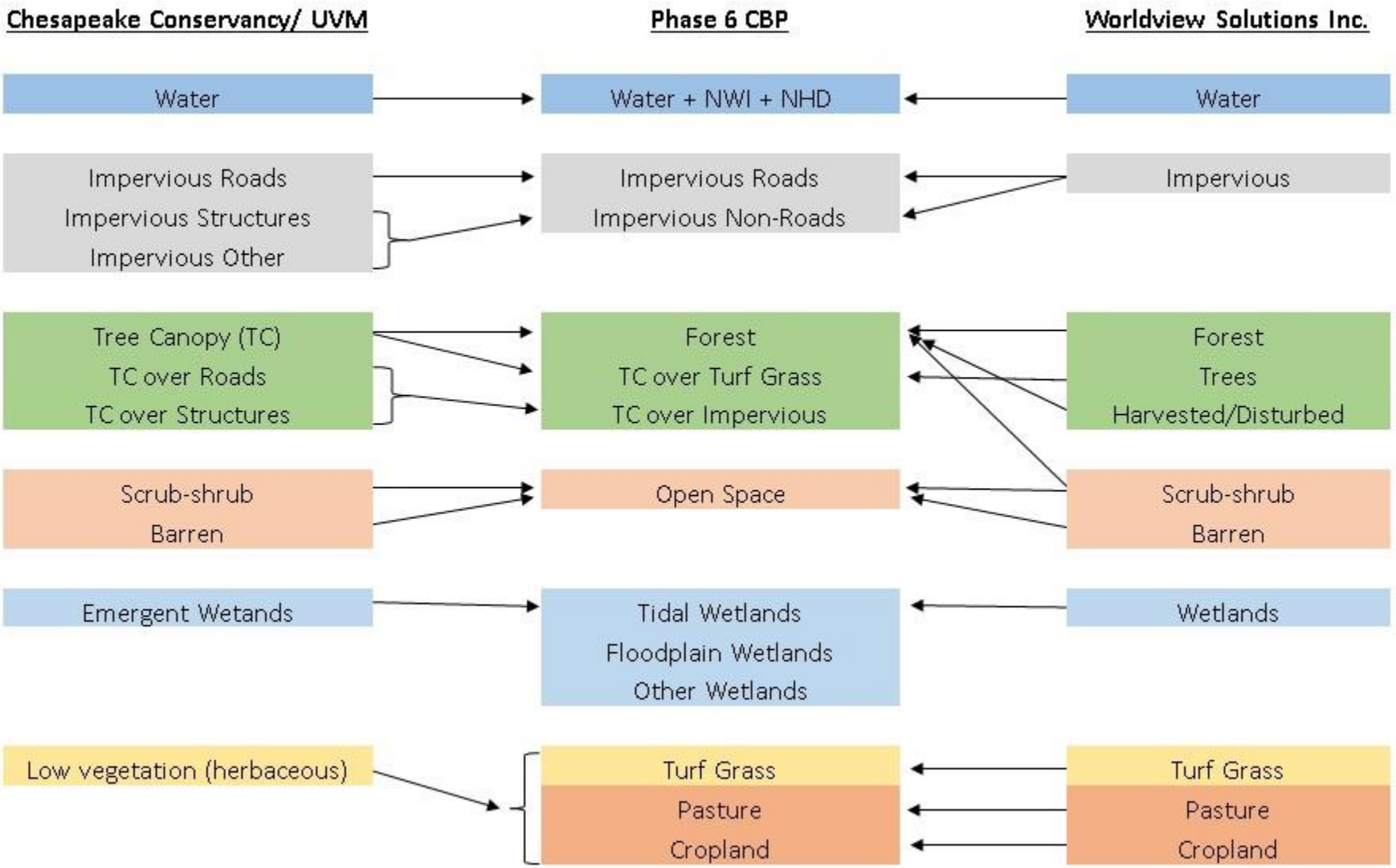
- **Initial semi-automated feature extraction with 900x the resolution of NLCD**
  - **Rule-based, object oriented image classification**
- **Manual corrections**

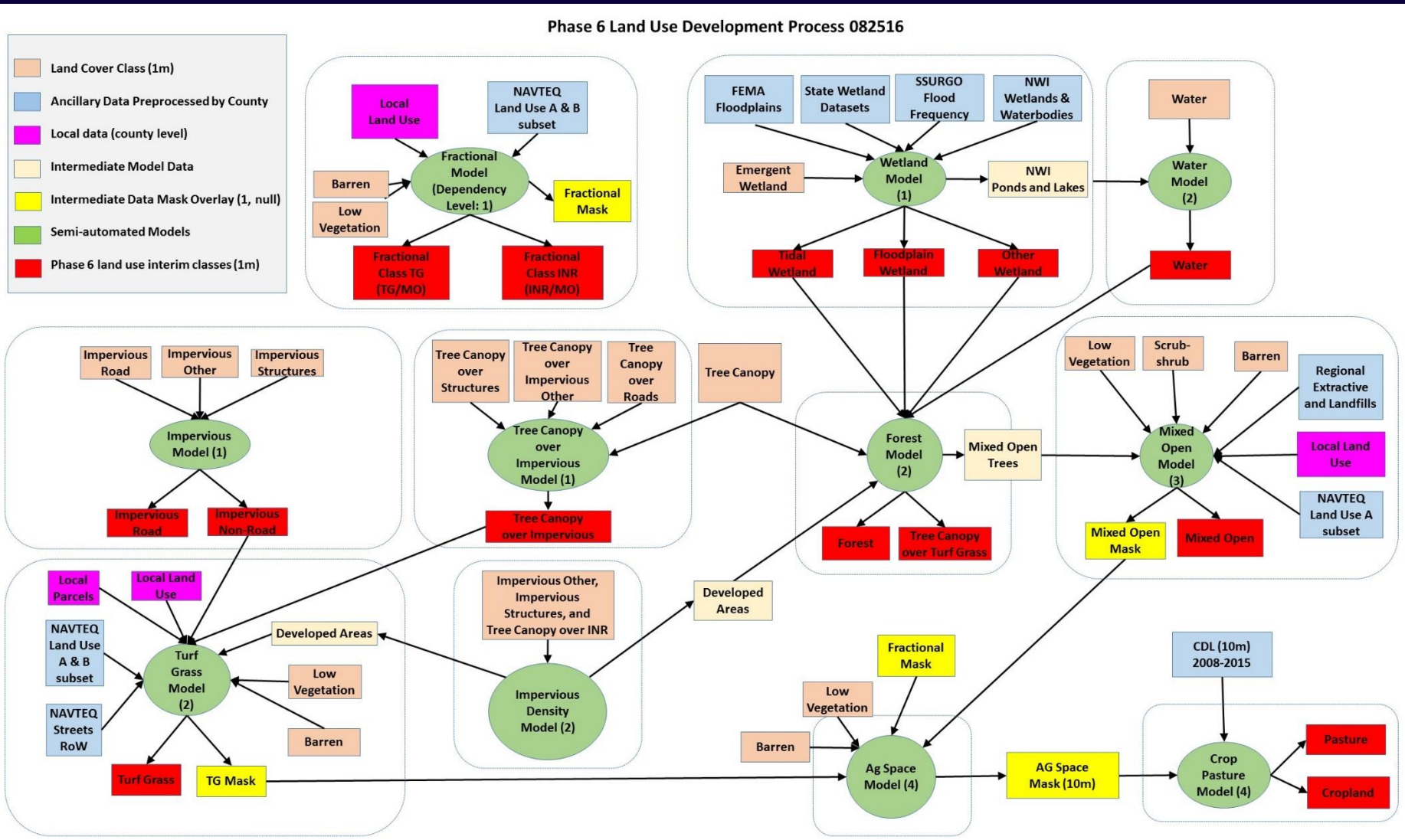


Frederick County
2013 Land Cover

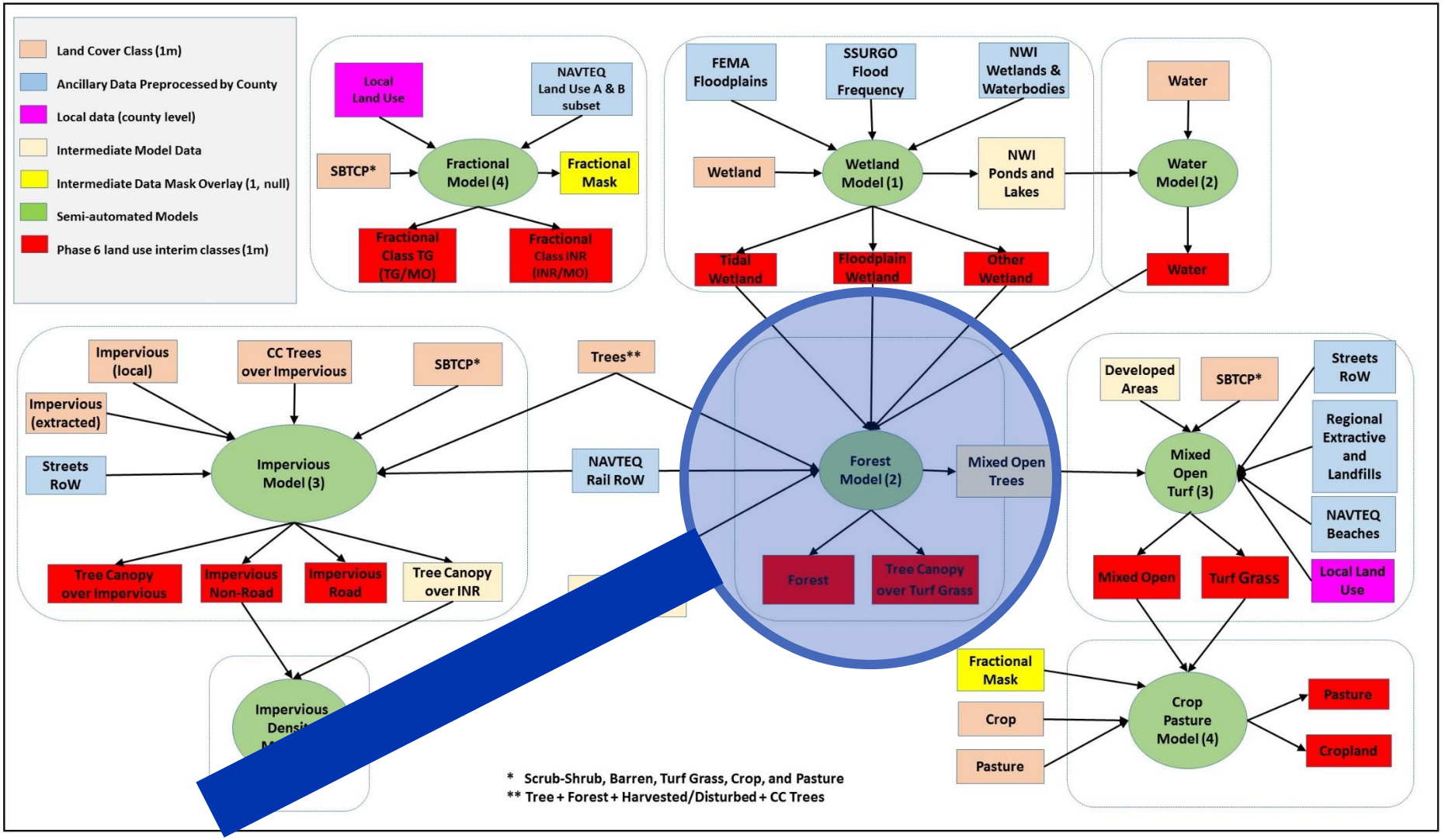


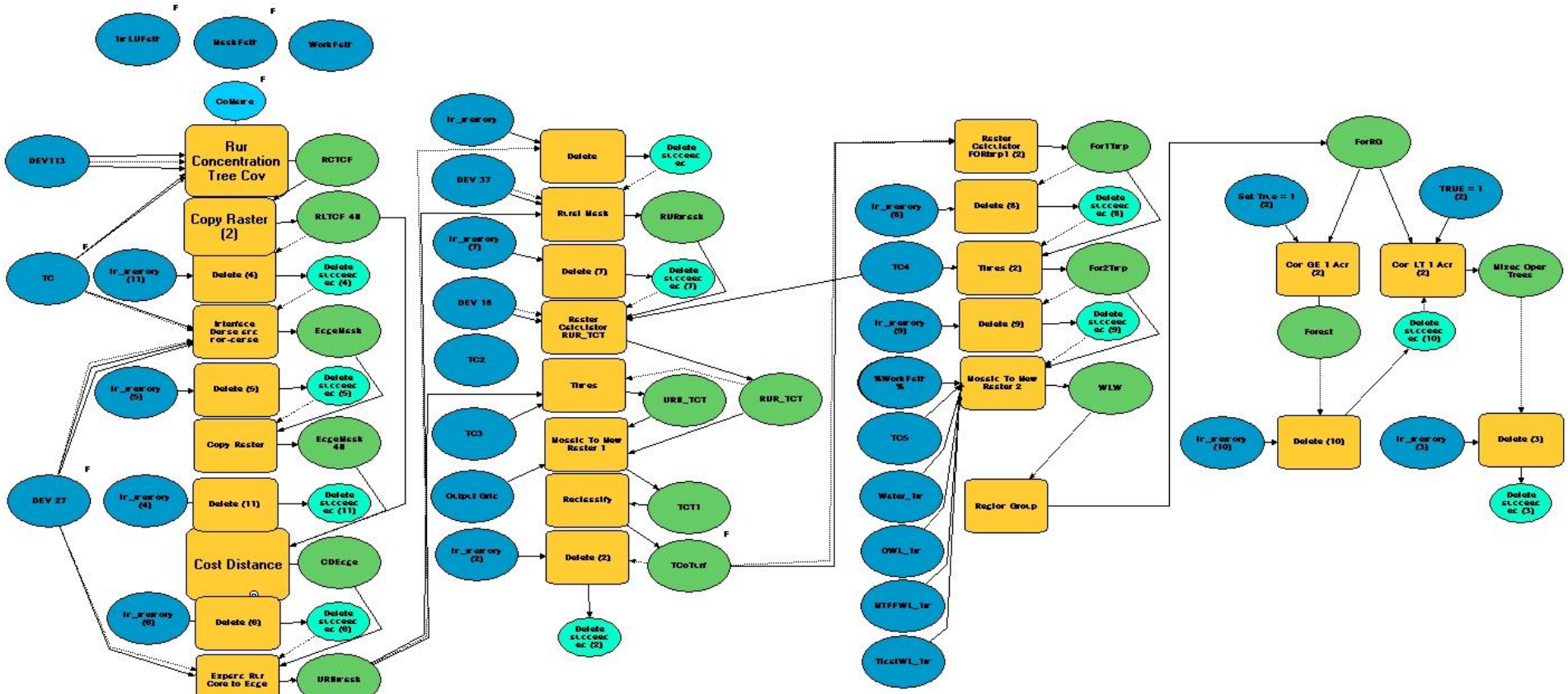
Land Cover to Land Use Crosswalk



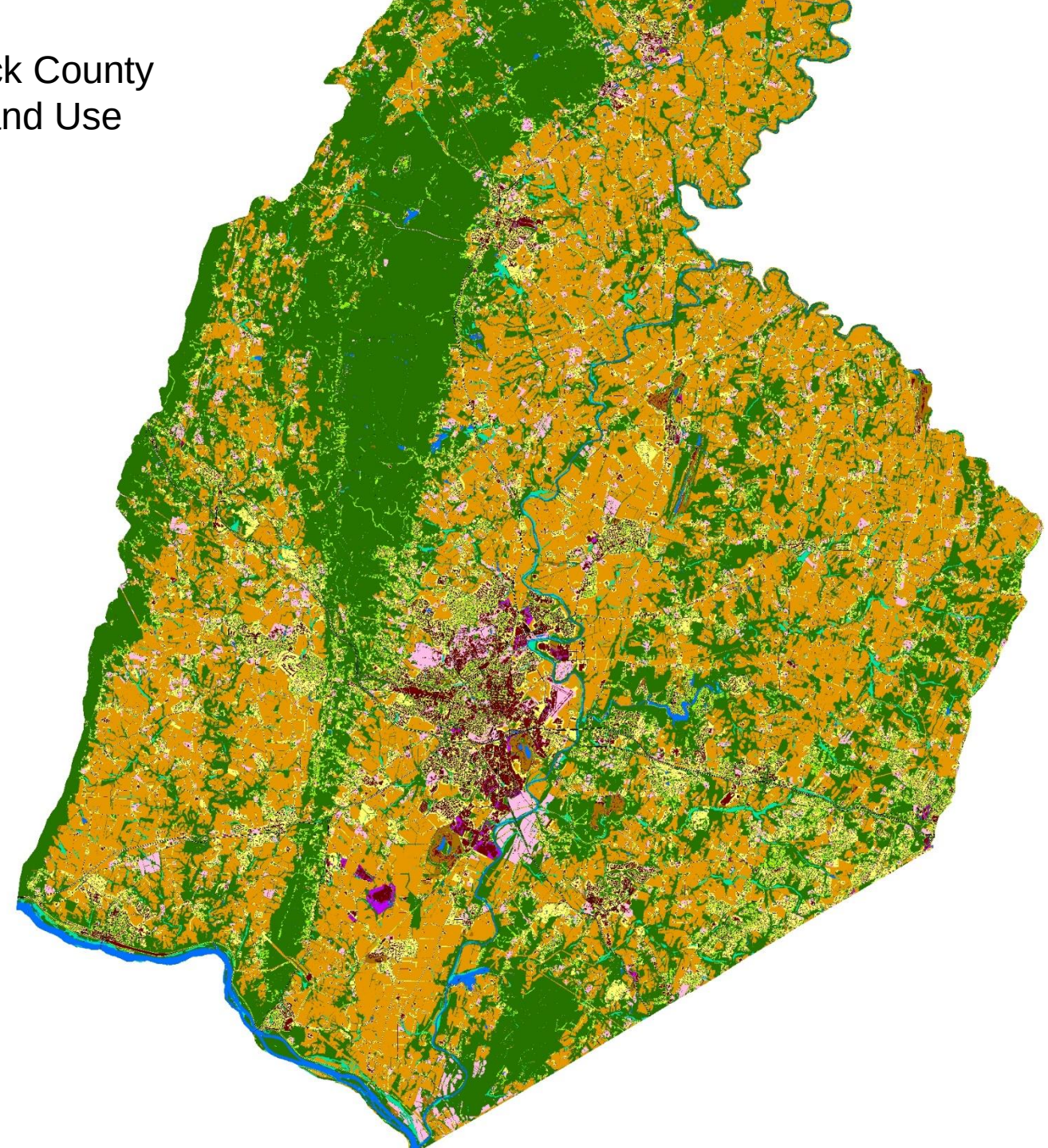

Phase 6 Land Use Development Process 082516
Land Cover Class (1m)
Ancillary Data Preprocessed by County
Local data (county level)
Intermediate Model Data
Intermediate Data Mask Overlay (1, null)
Semi-automated Models
Phase 6 land use interim classes (1m)
Local Land Use
NAVTEQ Land Use A & B subset
Barren
Low Vegetation
Fractional Model (Dependency Level: 1)
Fractional Mask
Fractional Class TG (TG/MO)
Fractional Class INR (INR/MO)
FEMA Floodplains
State Wetland Datasets
SSURGO Flood Frequency
NWI Wetlands & Waterbodies
Emergent Wetland
Wetland Model (1)
NWI Ponds and Lakes
Tidal Wetland
Floodplain Wetland
Other Wetland
Water
Water Model (2)
Water
Impervious Road
Impervious Other
Impervious Structures
Impervious Model (1)
Impervious Road
Impervious Non-Road
Tree Canopy over Structures
Tree Canopy over Impervious Other
Tree Canopy over Roads
Tree Canopy over Impervious Model (1)
Tree Canopy over Impervious
Tree Canopy
Forest Model (2)
Forest
Tree Canopy over Turf Grass
Mixed Open Trees
Low Vegetation
Scrub-shrub
Barren
Regional Extractive and Landfills
Local Land Use
NAVTEQ Land Use A subset
Mixed Open Model (3)
Mixed Open Mask
Mixed Open
Local Parcels
Local Land Use
NAVTEQ Land Use A & B subset
NAVTEQ Streets RoW
Turf Grass Model (2)
Developed Areas
Low Vegetation
Barren
Turf Grass
TG Mask
Impervious Other, Impervious Structures, and Tree Canopy over INR
Impervious Density Model (2)
Developed Areas
Fractional Mask
Low Vegetation
Barren
Ag Space Model (4)
AG Space Mask (10m)
CDL (10m) 2008-2015
Crop Pasture Model (4)
Pasture
Cropland

Phase 6 VA Land Use Development Process 072816



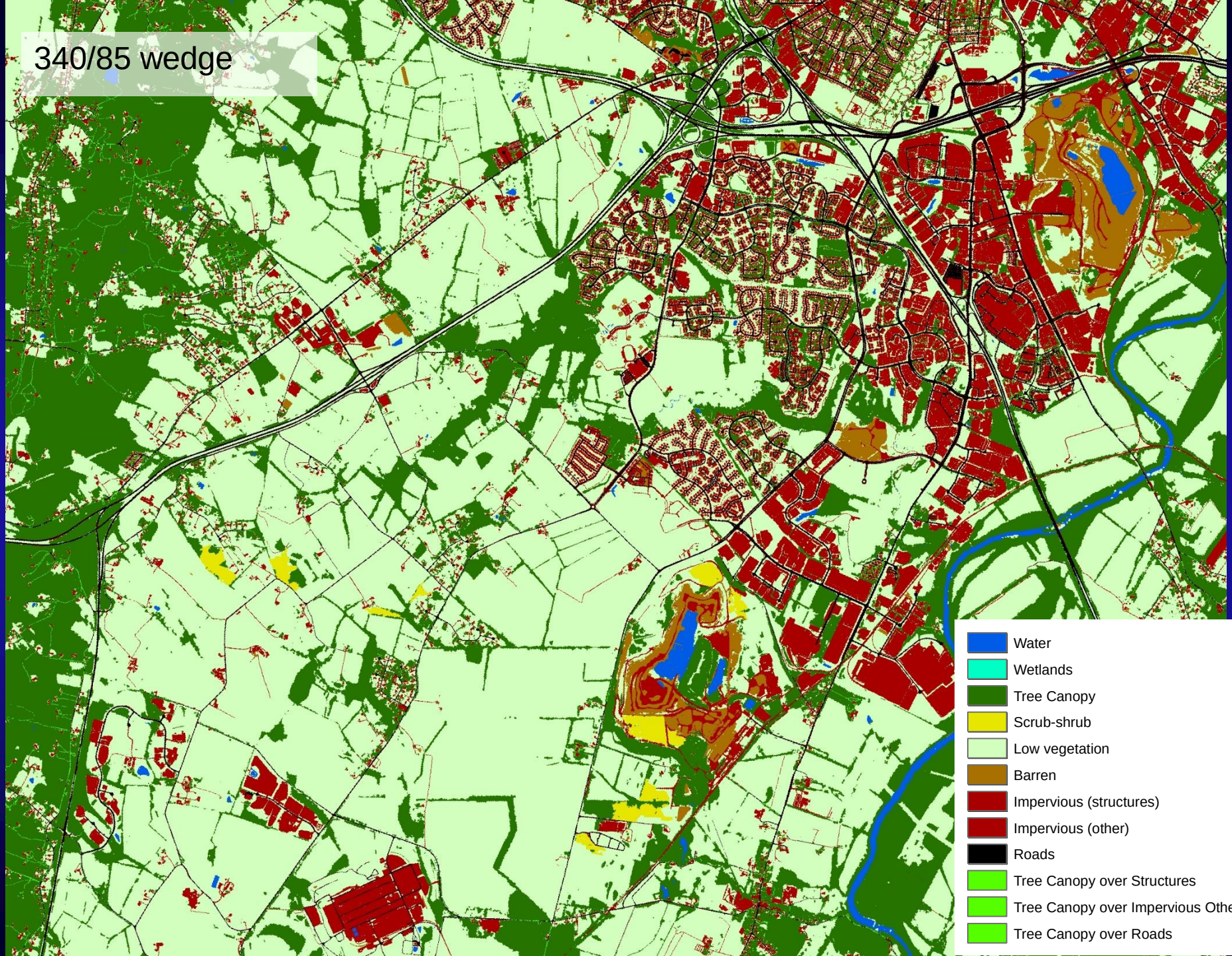

Rur Concentration Tree Cov
Copy Raster (2)
Delete (4)
Interface Dense erc for-cerse
Delete (5)
Copy Raster
Delete (11)
Cost Distance
Delete (8)
Expcrc Rur Core to Ecge
Delete
Rural Mask
Delete (7)
Raster Calculator RUR_TCT
Tires
Mosaic To New Raster 1
Reclassify
Delete (2)
Raster Calculator FORtrp1 (2)
Delete (6)
Tires (2)
Delete (9)
Mosaic To New Raster 2
Raster Group
Set True = 1 (2)
TRUE = 1 (2)
Cor GE 1 Acr (2)
Cor LT 1 Acr (2)
Mixed Oper Trees
Forest
Delete (10)
Delete (3)

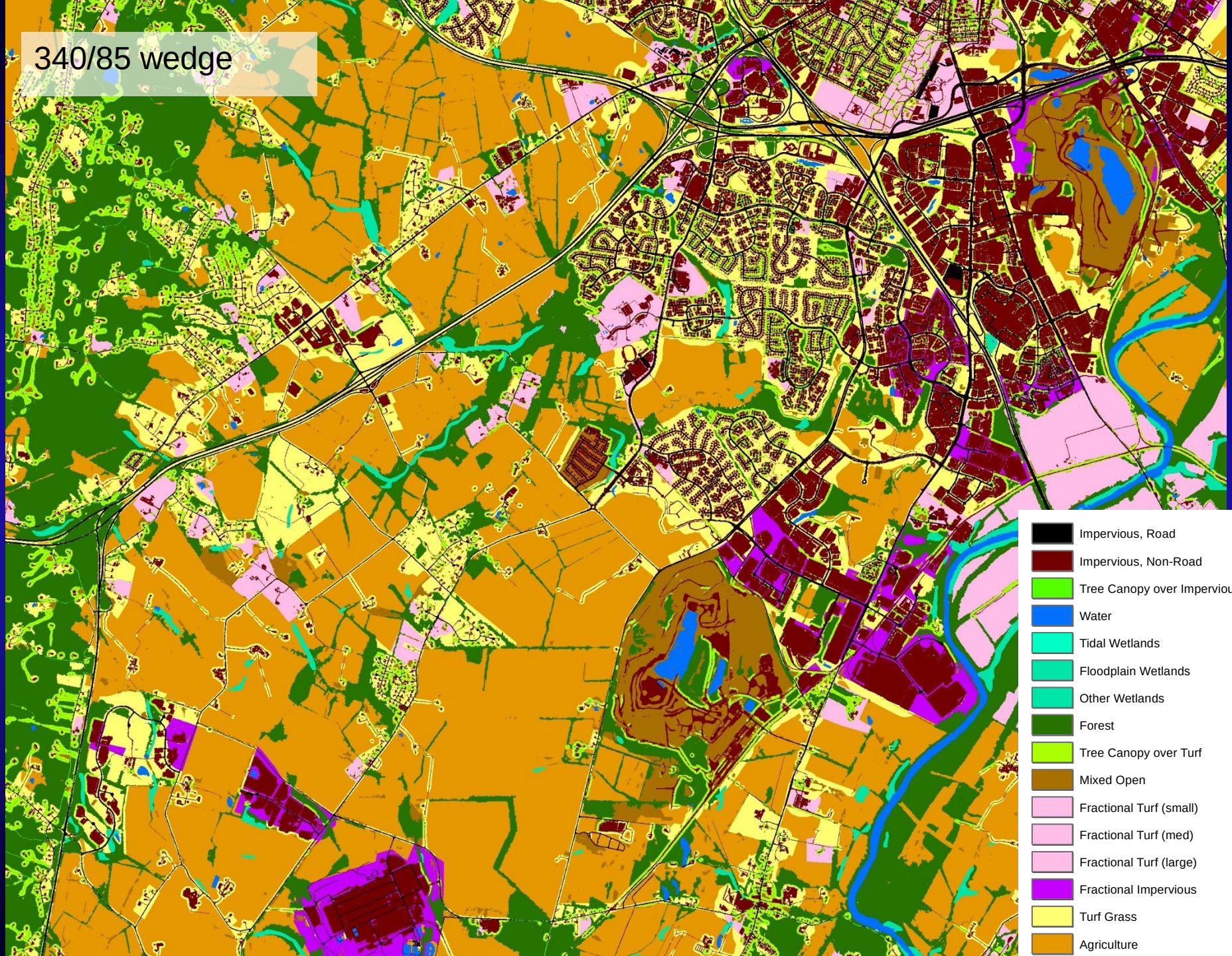
Frederick County
2013 Land Use



- Impervious, Road
- Impervious, Non-Road
- Tree Canopy over Impervious
- Water
- Tidal Wetlands
- Floodplain Wetlands
- Other Wetlands
- Forest
- Tree Canopy over Turf
- Mixed Open
- Fractional Turf (small)
- Fractional Turf (med)
- Fractional Turf (large)
- Fractional Impervious
- Turf Grass
- Agriculture


340/85 wedge
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


340/85 wedge
Water
Wetlands
Tree Canopy
Scrub-shrub
Low vegetation
Barren
Impervious (structures)
Impervious (other)
Roads
Tree Canopy over Structures
Tree Canopy over Impervious Other
Tree Canopy over Roads


340/85 wedge
Impervious, Road
Impervious, Non-Road
Tree Canopy over Impervious
Water
Tidal Wetlands
Floodplain Wetlands
Other Wetlands
Forest
Tree Canopy over Turf
Mixed Open
Fractional Turf (small)
Fractional Turf (med)
Fractional Turf (large)
Fractional Impervious
Turf Grass
Agriculture

Phase 6 Error Rates for 2013 conditions

Census of Agriculture (2012)

- **Mean: 83.8% (59.8% - 95.2%) (0.05 – 0.95 percentiles)**
- **Applied to cropland, pasture, mixed open, and turf grass**
- **VA Turf Grass assigned an accuracy of 72%. VA crop and pasture may receive accuracies of 95% and 91% respectively.**

Impervious roads: 92% (74% - 100%)

Impervious Non-Roads: 93% (88% - 97%)

Tree Canopy over Impervious: 59% (19% - 92%)

Tree Canopy over Turf Grass: 94% (83% - 99%)

Water: 98% (96% - 100%)

Forest: 98% (96% - 99%)

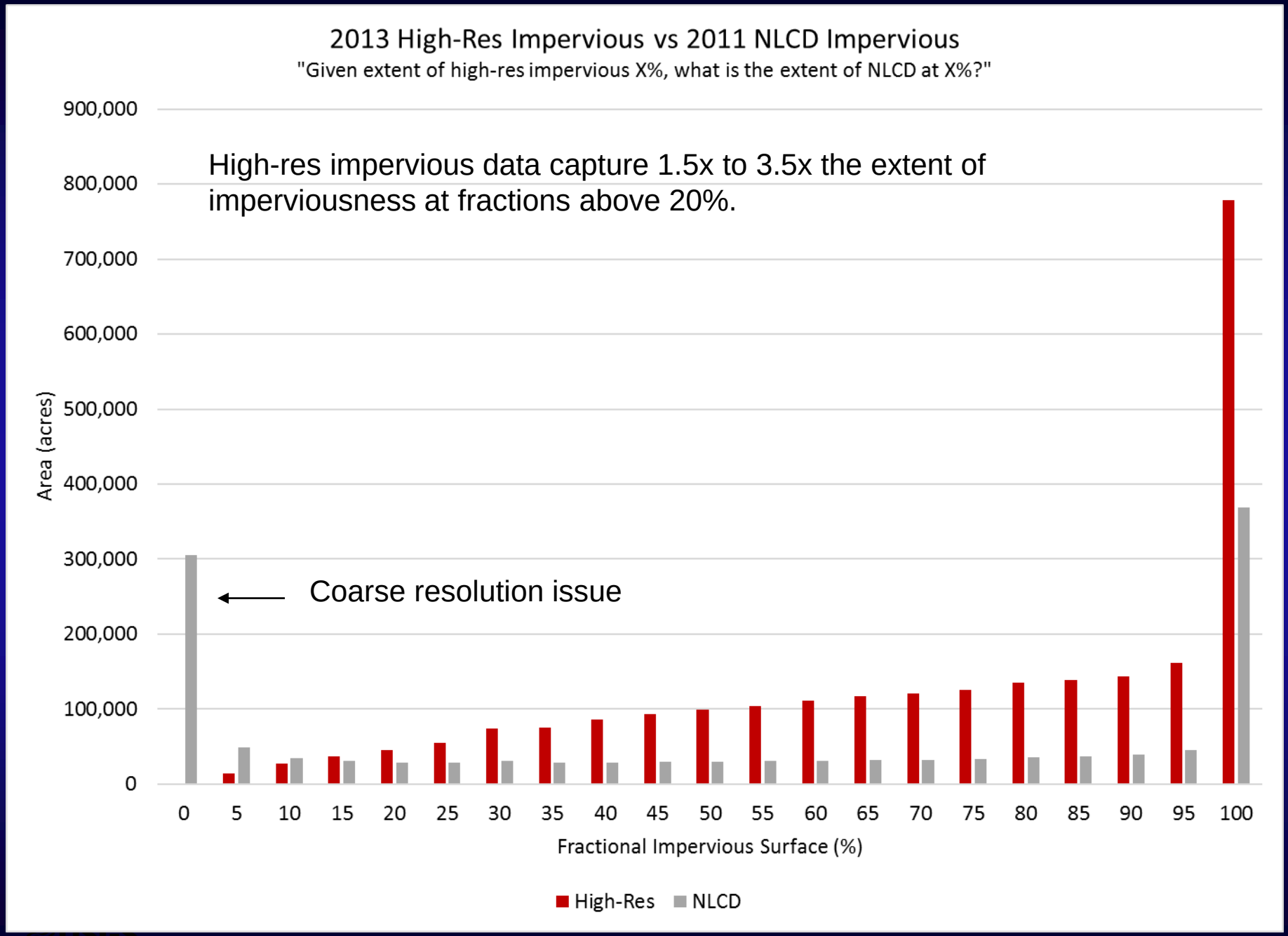
Wetlands: 95% assigned to all because NWI was “burned in”

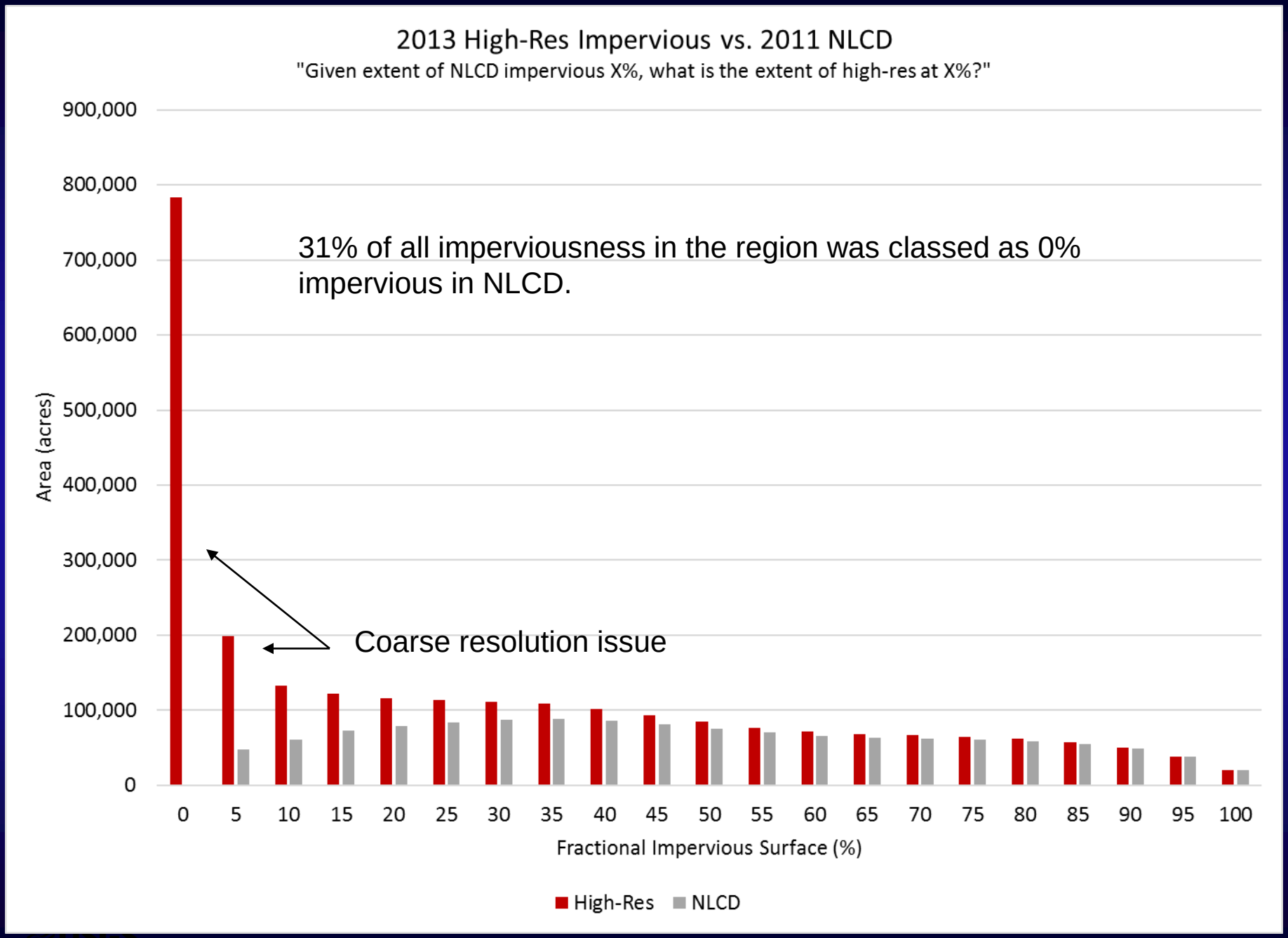
USGS

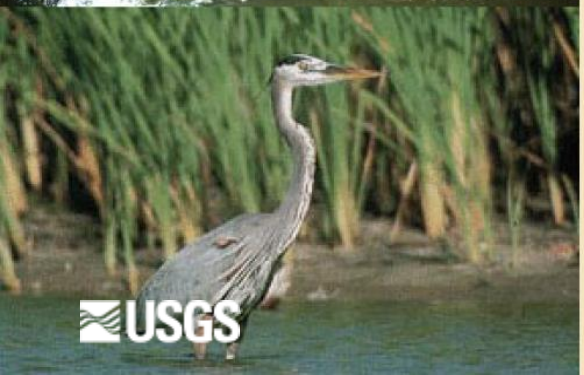
Comparison of P6 & P532 Land Use

	P6LU13	P6SB13	P6SB10	P532SB10
Impervious	1,883,846	1,883,204	1,834,926	1,386,397
Pervious	3,777,846	3,465,395	3,341,163	3,620,800
Natural	24,573,735	24,733,306	24,781,361	25,740,416
Mixed Open	1,198,107	1,408,175	1,400,542	239,209
Cropland	3,601,367	4,095,520	4,045,995	4,497,514
Pasture	4,780,365	4,227,579	4,409,854	4,670,073
Water	758,028	759,868	759,206	418,638
Total	40,573,294	40,573,047	40,573,047	40,573,047

USGS


2013 High-Res Impervious vs 2011 NLCD Impervious
"Given extent of high-res impervious X%, what is the extent of NLCD at X%?"
High-res impervious data capture 1.5x to 3.5x the extent of imperviousness at fractions above 20%.
Coarse resolution issue
Area (acres)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Fractional Impervious Surface (%)
High-Res
NLCD


2013 High-Res Impervious vs. 2011 NLCD
"Given extent of NLCD impervious X%, what is the extent of high-res at X%?"
31% of all imperviousness in the region was classed as 0% impervious in NLCD.
Coarse resolution issue
Area (acres)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Fractional Impervious Surface (%)
High-Res
NLCD



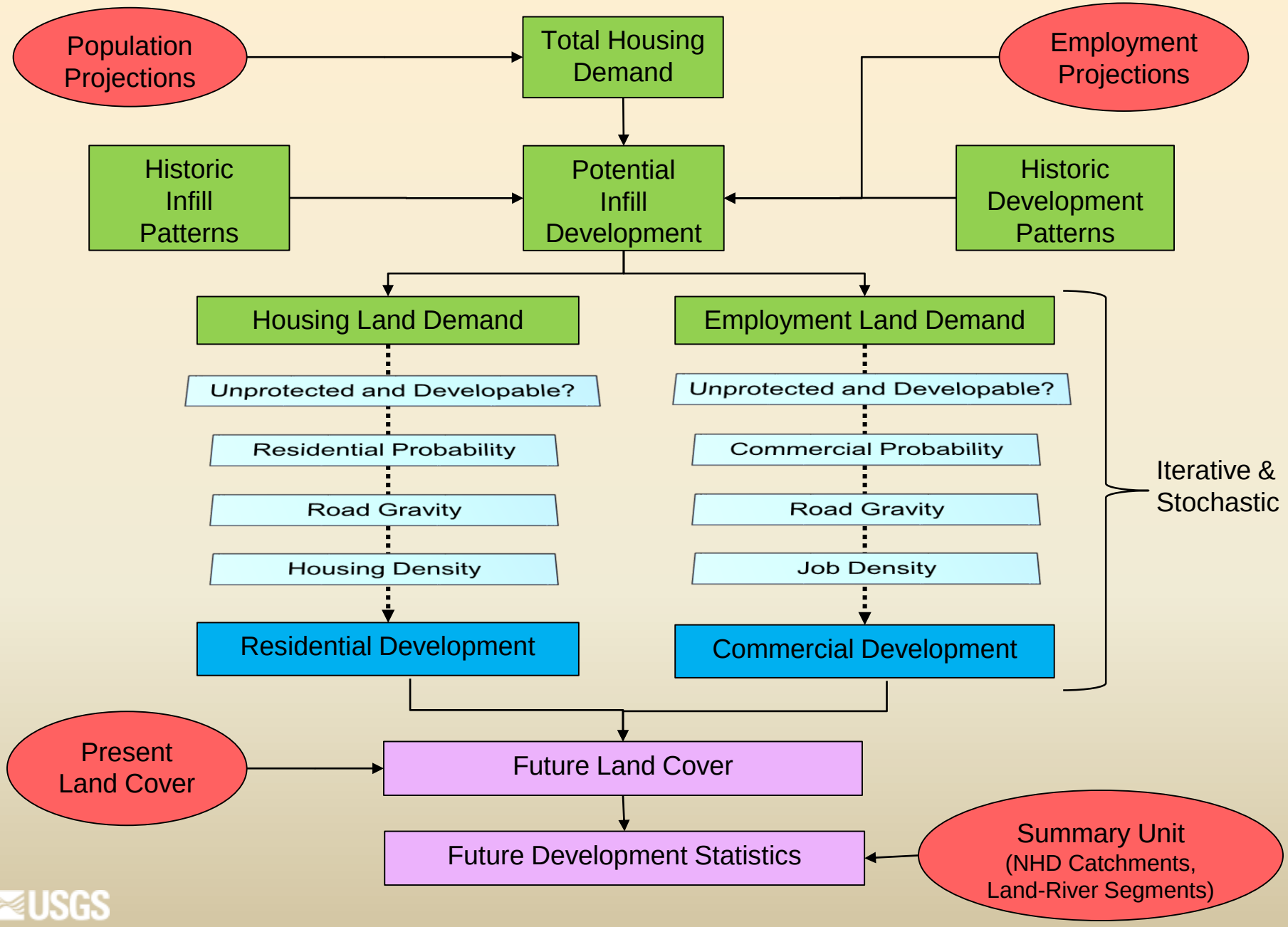
Chesapeake Bay Program
A Watershed Partnership

Forecasting Urban Growth in the Chesapeake Bay Watershed: 2025, 2040, and 2050

Karl Berger, Chair, Land Use Workgroup
Peter Claggett, Coordinator, Land Use Workgroup

Urban Stormwater Workgroup
May 15, 2017

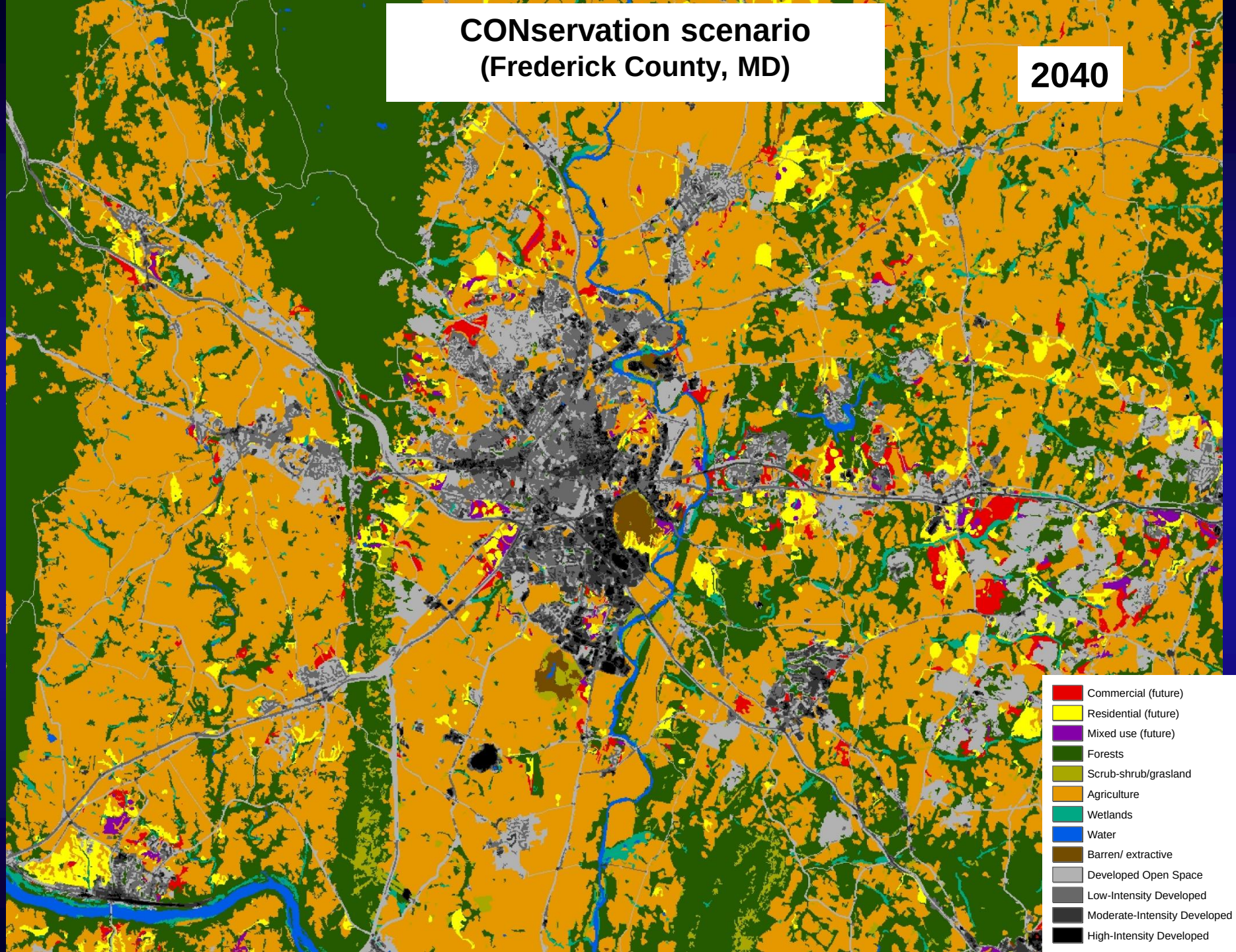
Chesapeake Bay Land Change Model v3a

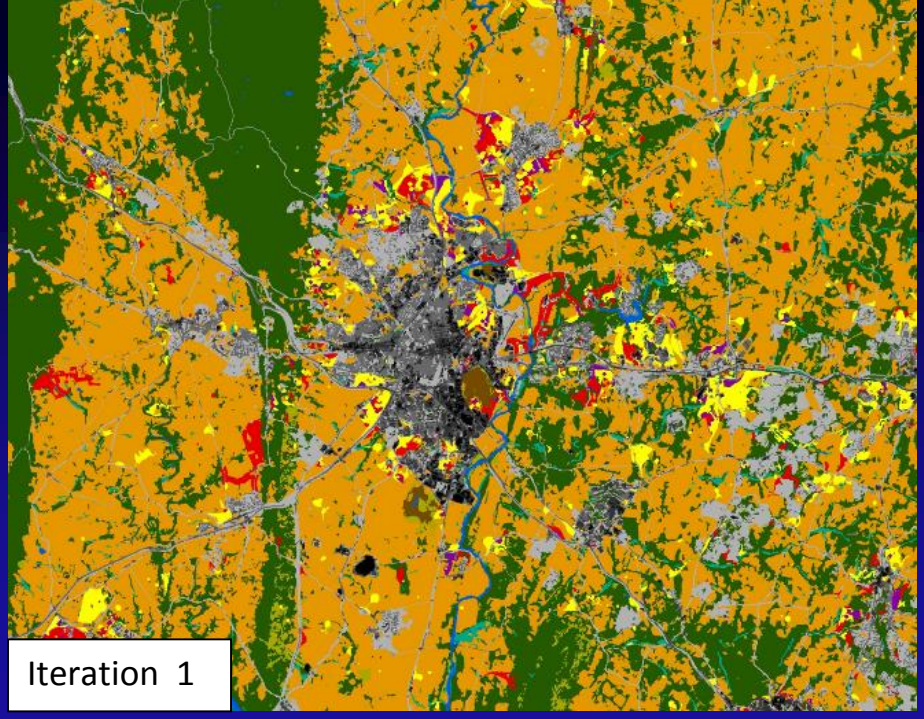


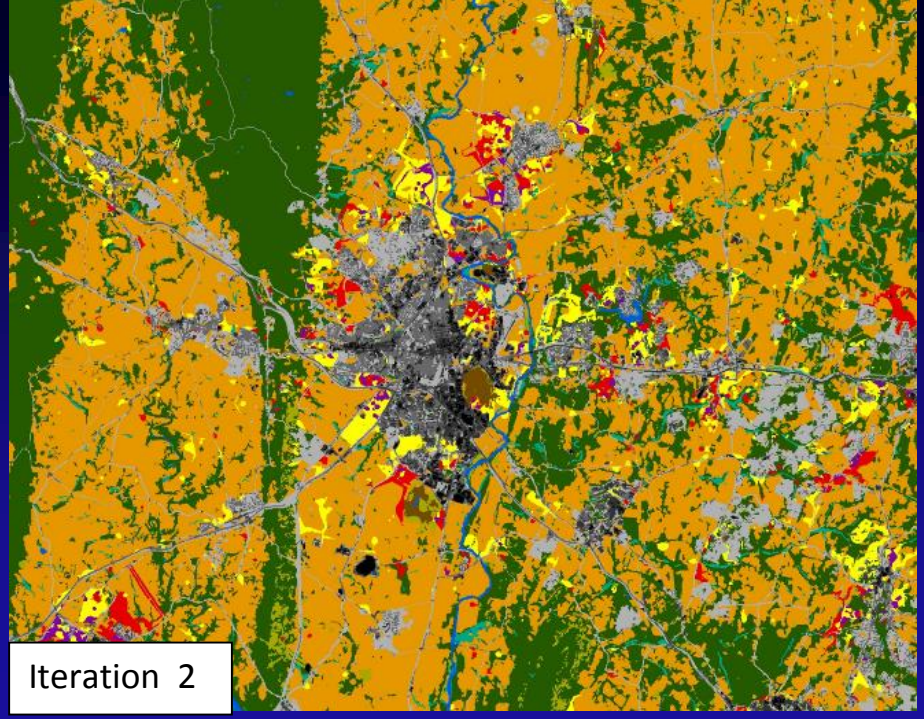
USGS

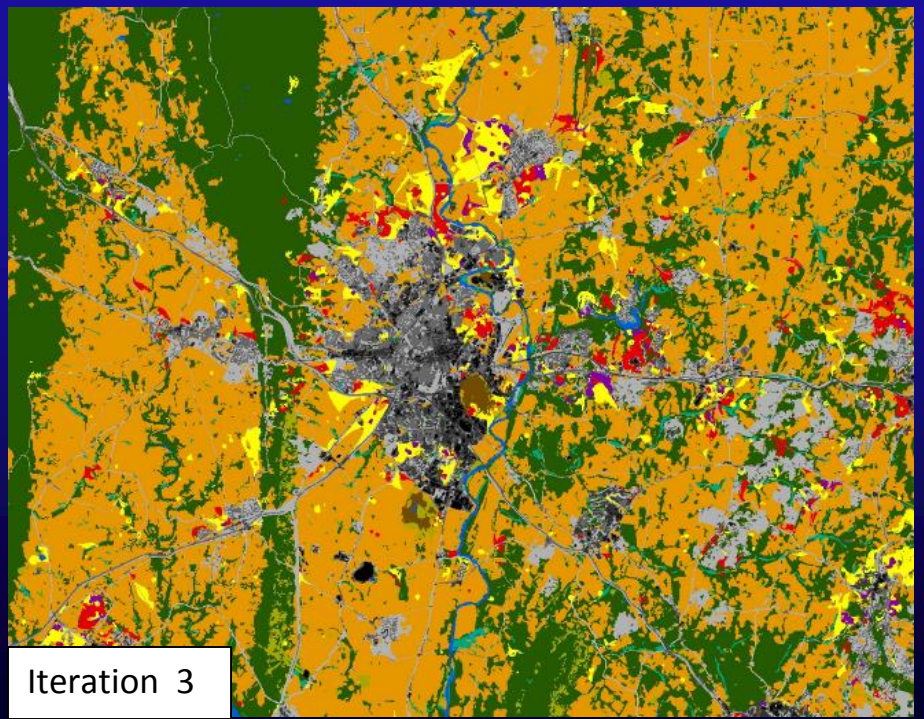
CONservation scenario
(Frederick County, MD)

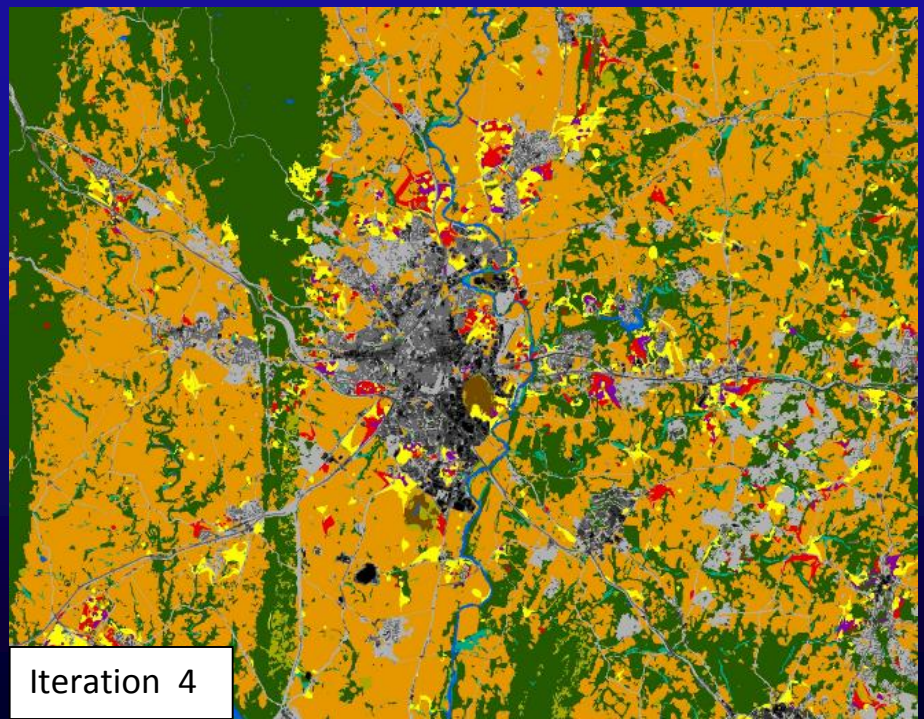
2040

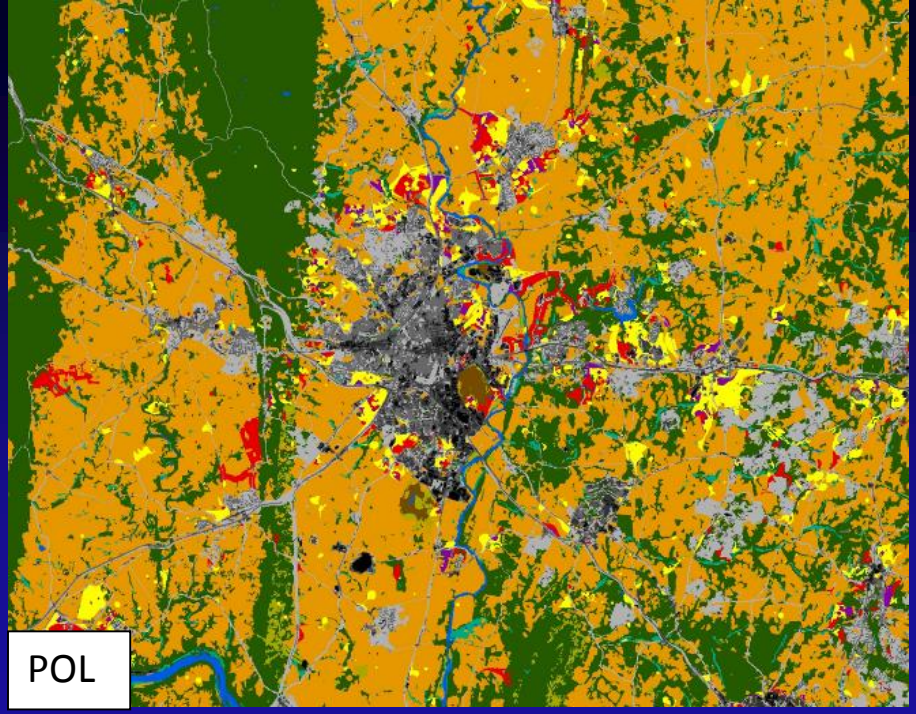


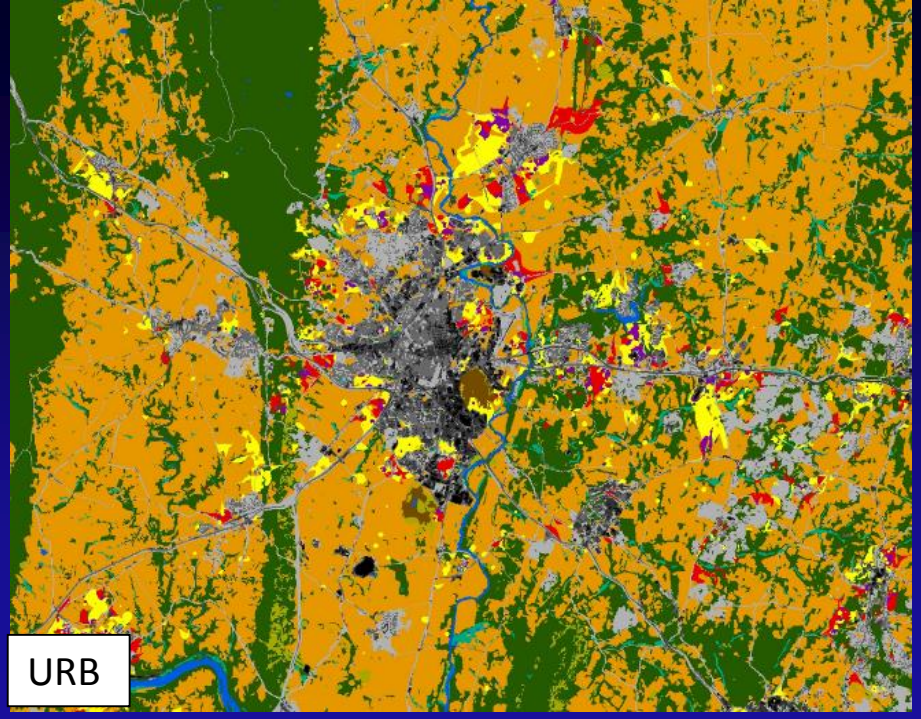

Iteration 1

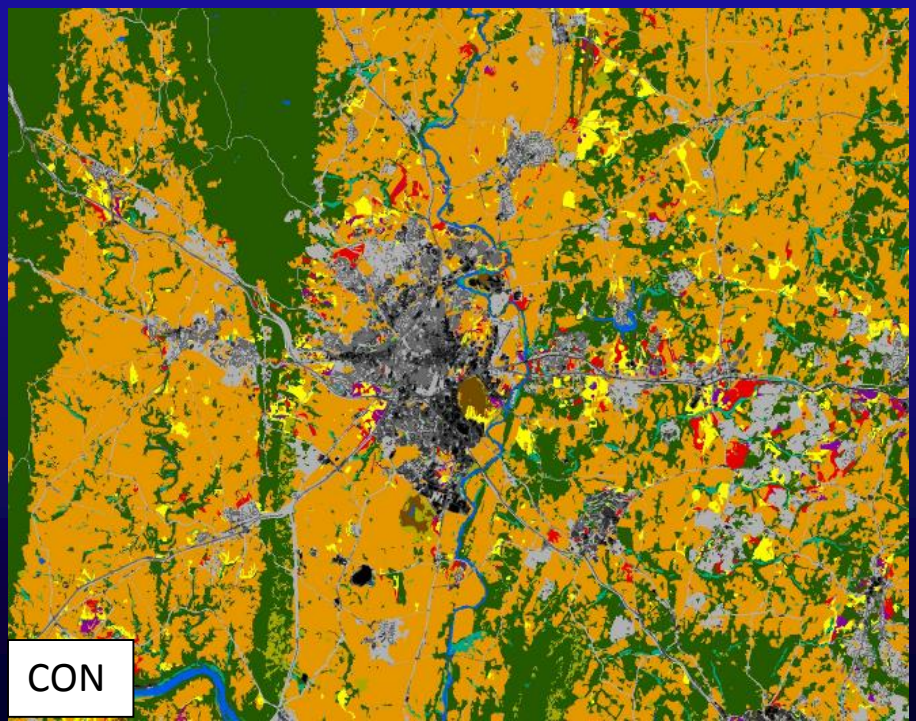

Iteration 2

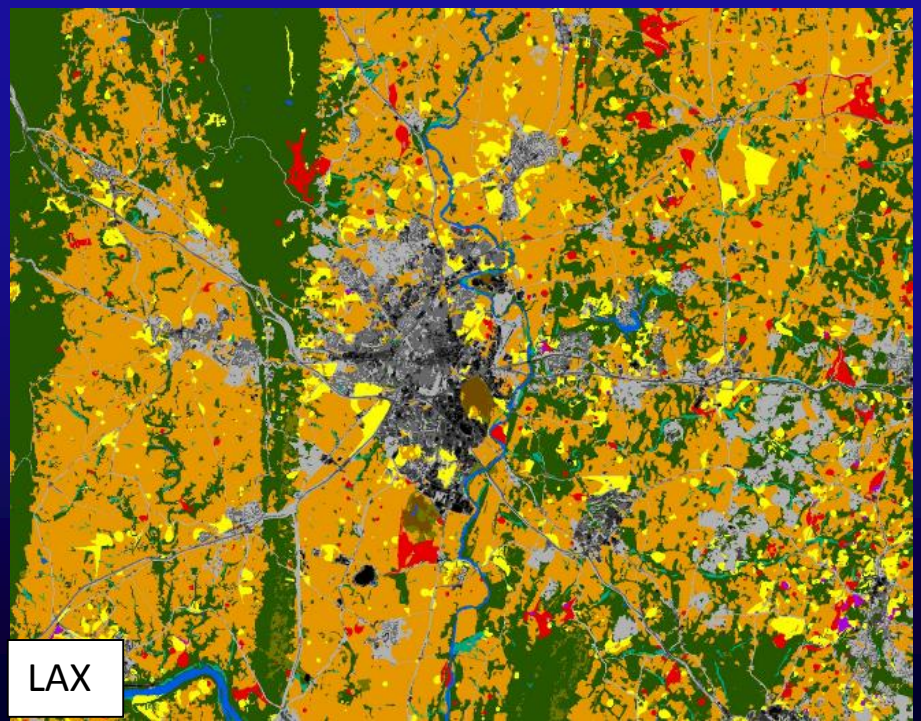

Iteration 3


Iteration 4


POL


URB

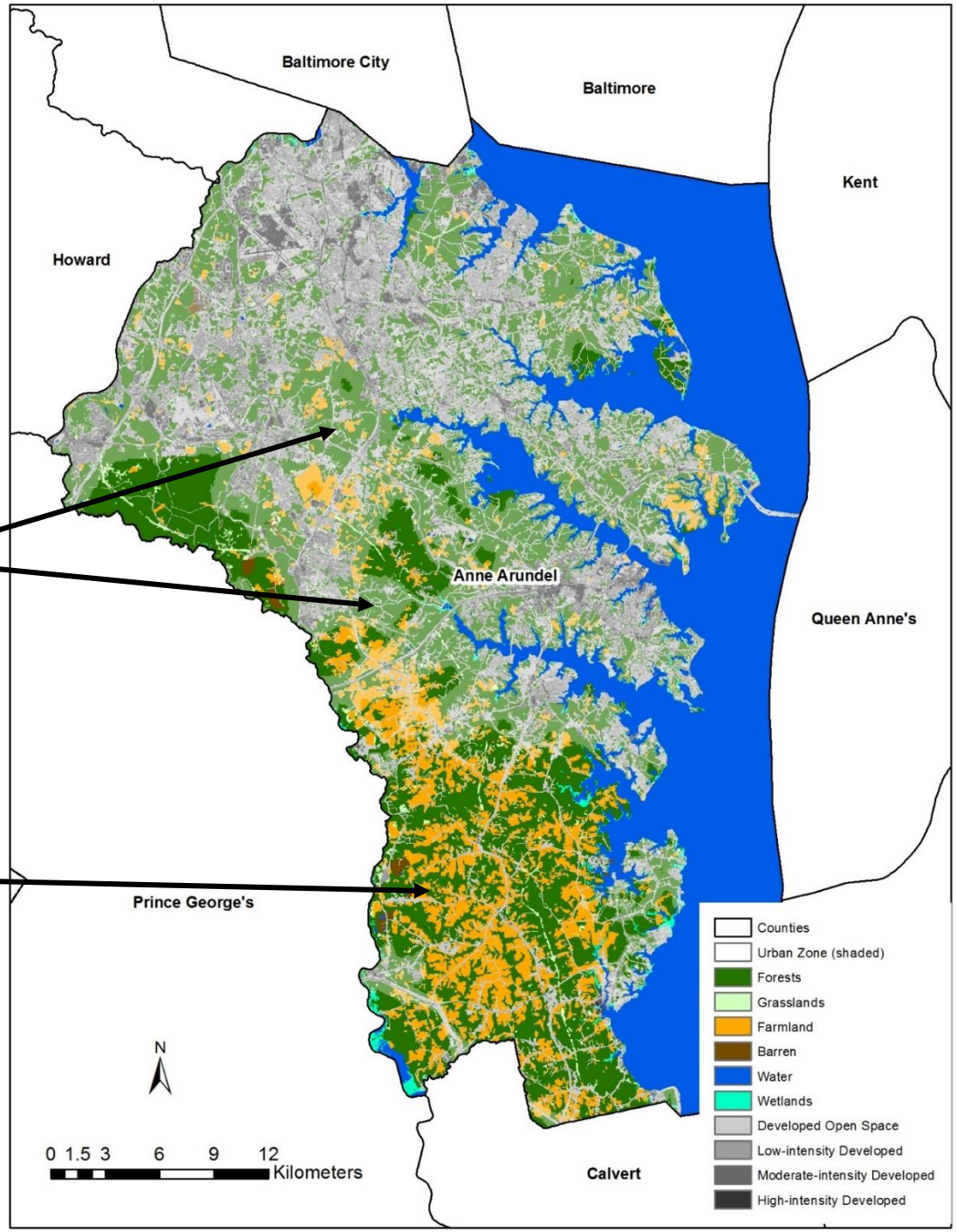

CON


LAX

Why development may disproportionately impact forests:

Unprotected forests within the urban zone with high demand for land and probability of development

Agriculture dominant in rural zone but demand for land is relatively low



USGS

Scenario Results For Review
Scales: P6 Land-River Segments & Counties

1. New development acres
2. Future population on sewer and septic
3. Residential land consumption rate (acres / household)
4. Commercial land consumption rate (acres/ job)
4. Forest acres converted to development
5. Farmland acres converted to development
6. Δ Total Nitrogen (# / acre / yr.)
7. Δ Total Phosphorus (# / acre / yr.)
8. Δ Total Sediment (tons / acre / yr.)

USGS

Future Scenario Results for Maryland

POL Scenario	2020	2030	2040
Total Development	27,858	53,610	72,360
Forest Loss	13,795	25,699	34,075
Farmland Loss	9,980	20,223	27,947
Forest:Farm Conversion Ratio	1.38	1.27	1.22

URB Scenario	2020	2030	2040
Total Development	23,179	44,221	59,318
Forest Loss	11,353	20,877	27,559
Farmland Loss	8,243	16,693	22,921
Forest:Farm Conversion Ratio	1.38	1.25	1.20

CON Scenario	2020	2030	2040
Total Development	24,848	48,404	63,203
Forest Loss	14,094	26,149	33,473
Farmland Loss	9,289	19,481	26,175
Forest:Farm Conversion Ratio	1.52	1.34	1.28

LAX Scenario	2020	2030	2040
Total Development	38,677	74,625	102,369
Forest Loss	17,288	32,737	44,576
Farmland Loss	16,515	32,481	44,896
Forest:Farm Conversion Ratio	1.05	1.01	0.99

Conclusions:

Infill, redevelopment, and densification achieve the greatest reductions in future greenfield development, minimizing impacts to BOTH forests and farms.

Conserving prime farmland and large forest tracts (>250 acres) ensures that the most valuable natural assets remain intact.

USGS

Scenario Evaluation Metrics
Scale: P6 Land-River Segments & Counties

1. New impervious per capita
2. Large forest patches converted / total forest converted
3. Prime soils converted / total farmland converted
4. Forest and farmland fragmentation
5. Concentration or excess of manure
6. Loss of BMPs (due to the conversion of farmland)

USGS

Proposed Alternative Future Scenarios

"Historical Trends": growth follows patterns prevalent over previous decade.

"Current Policy": (with zoning): direct growth to areas either zoned for it and/or with necessary infrastructure and capacity to support it.

"Land Conservation": protect state and local priority conservation areas.

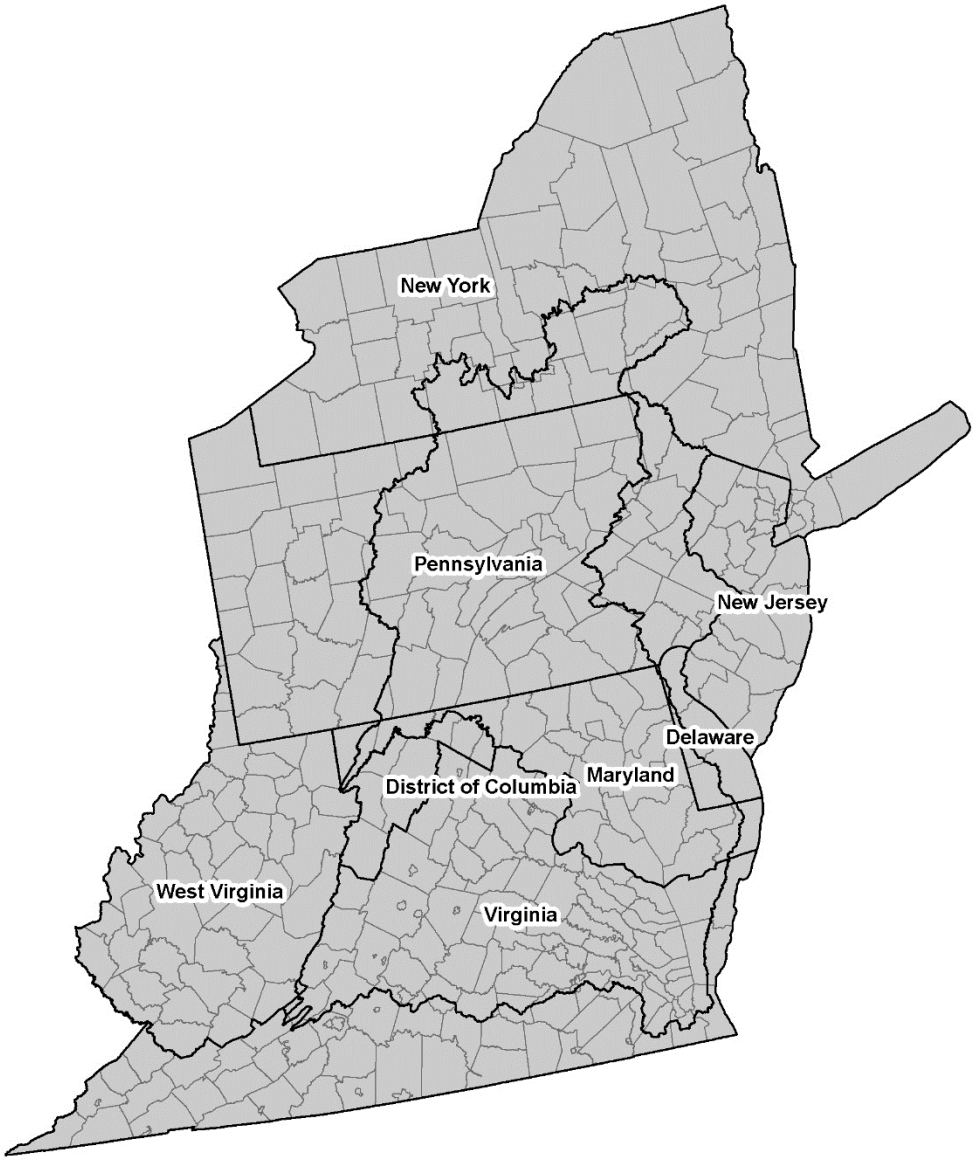
"Rural Character": up-zone urban areas and down-zone rural areas.

"Infill and Redevelopment": direct more growth into urban areas.

Approved by Land Use Workgroup
Discussed in Alternative Futures Workshop:
Alternative Futures: Accounting for Growth in the Chesapeake Bay Watershed USGS sponsored workshop on September 15, 2011, https://pubs.usgs.gov/of/2012/1216/OFR2012-1216.pdf

USGS

Chesapeake Bay Future Land Use Scenario Domain



USGS

Pennsylvania

regressions - Notepad

File Edit Format View Help

```
Logistic Regression Model

 lrm(formula = Value ~ LnCD_UAC00 + LnCD_Res01 + LnCD_Com01 +
     LnSlope, data = RES_Sample)

                       Model Likelihood      Discrimination    Rank Discrim.
                          Ratio Test            Indexes          Indexes
 Obs         140732    LR chi2    138372.53    R2       0.835    C       0.969
  0           70366    d.f.               4    g        4.801    Dxy     0.938
  1           70366    Pr(> chi2)   <0.0001    gr     121.664    gamma   0.939
 max |deriv|  8e-10                           gp       0.474    tau-a   0.469
                                              Brier    0.055

           Coef    S.E.   Wald Z  Pr(>|Z|)
 Intercept  24.2414 0.1386  174.89 <0.0001
 LnCD_UAC00 -0.4450 0.0101  -43.95 <0.0001
 LnCD_Res01 -0.6075 0.0109  -55.60 <0.0001
 LnCD_Com01 -1.2248 0.0109 -112.62 <0.0001
 LnSlope    -0.4026 0.0113  -35.52 <0.0001

Logistic Regression Model

 lrm(formula = Value ~ LnCD_UAC00 + LnCD_Res01 + LnCD_Com01 +
     LnSlope, data = COM_Sample)

                       Model Likelihood      Discrimination    Rank Discrim.
                          Ratio Test            Indexes          Indexes
 Obs         209082    LR chi2    199801.99    R2       0.821    C       0.965
  0          104541    d.f.               4    g        4.508    Dxy     0.929
  1          104541    Pr(> chi2)   <0.0001    gr      90.775    gamma   0.930
 max |deriv|  4e-09                           gp       0.470    tau-a   0.465
                                              Brier    0.059

           Coef    S.E.   Wald Z  Pr(>|Z|)
 Intercept  22.4408 0.1090  205.88 <0.0001
 LnCD_UAC00 -0.8478 0.0082 -103.65 <0.0001
 LnCD_Res01 -0.3555 0.0103  -34.66 <0.0001
 LnCD_Com01 -0.9236 0.0079 -117.27 <0.0001
 LnSlope    -0.3421 0.0094  -36.21 <0.0001
```

Virginia

regressions - Notepad

File Edit Format View Help

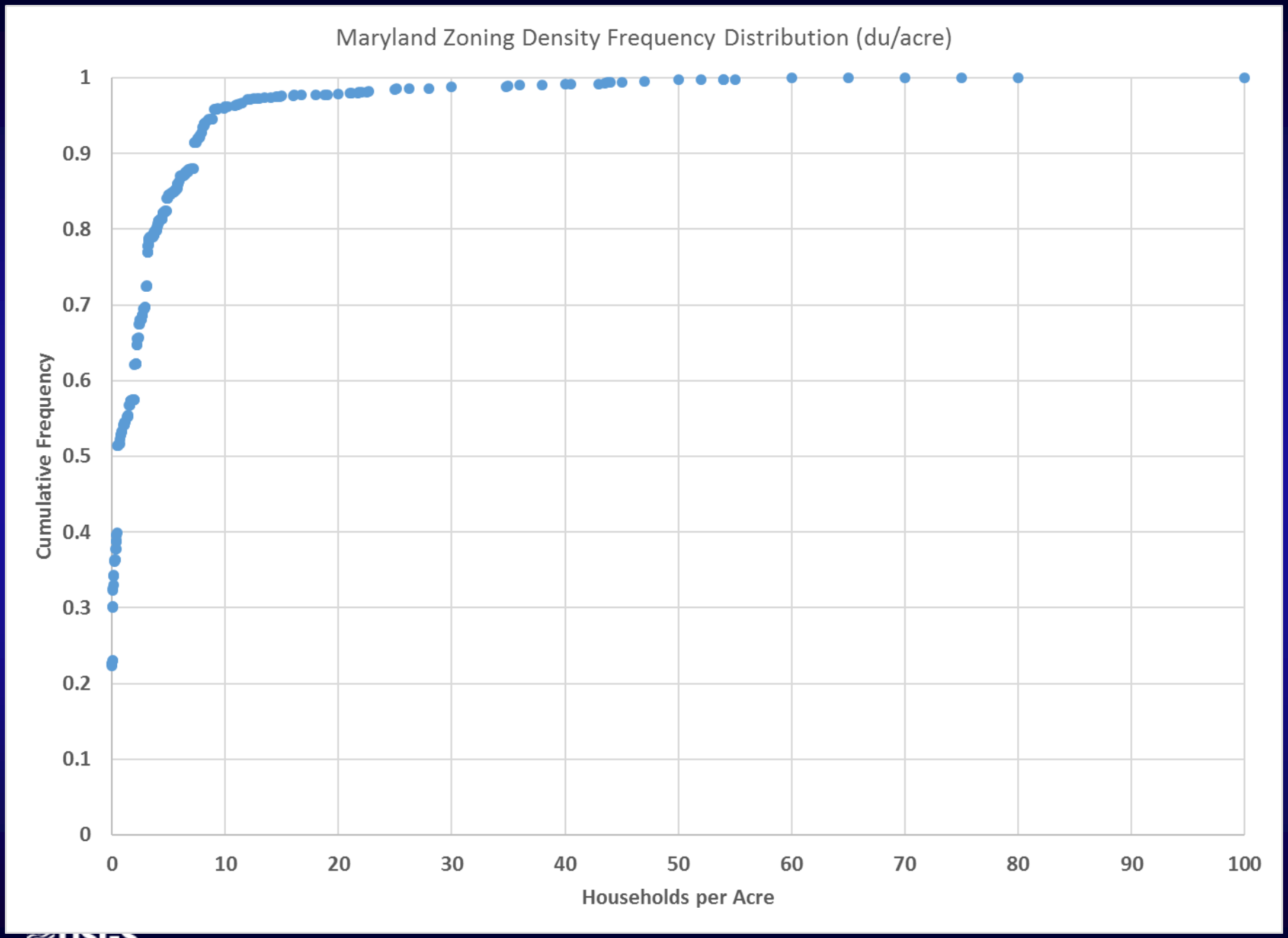
```
Logistic Regression Model

 lrm(formula = Value ~ LnCD_UAC00 + LnCD_Res01 + LnCD_Com01 +
     LnSlope, data = RES_Sample)

                       Model Likelihood      Discrimination    Rank Discrim.
                          Ratio Test            Indexes          Indexes
 Obs         115570    LR chi2    130081.11    R2       0.901    C       0.985
  0           57785    d.f.               4    g        5.755    Dxy     0.969
  1           57785    Pr(> chi2)   <0.0001    gr     315.855    gamma   0.970
 max |deriv|  8e-10                           gp       0.488    tau-a   0.485
                                              Brier    0.032

           Coef    S.E.   Wald Z Pr(>|Z|)
 Intercept  27.3417 0.1972 138.62 <0.0001
 LnCD_UAC00 -0.4922 0.0134 -36.65 <0.0001
 LnCD_Res01 -0.7922 0.0185 -42.93 <0.0001
 LnCD_Com01 -1.2247 0.0159 -76.93 <0.0001
 LnSlope    -0.3871 0.0129 -29.96 <0.0001

Logistic Regression Model

 lrm(formula = Value ~ LnCD_UAC00 + LnCD_Res01 + LnCD_Com01 +
     LnSlope, data = COM_Sample)

                       Model Likelihood      Discrimination    Rank Discrim.
                          Ratio Test            Indexes          Indexes
 Obs         217756    LR chi2    229526.81    R2       0.869    C       0.977
  0          108878    d.f.               4    g        5.142    Dxy     0.955
  1          108878    Pr(> chi2)   <0.0001    gr     171.015    gamma   0.956
 max |deriv|  2e-09                           gp       0.482    tau-a   0.477
                                              Brier    0.042

           Coef    S.E.   Wald Z Pr(>|Z|)
 Intercept  26.8986 0.1318 204.02 <0.0001
 LnCD_UAC00 -0.6387 0.0082 -78.35 <0.0001
 LnCD_Res01 -0.9353 0.0135 -69.09 <0.0001
 LnCD_Com01 -0.8398 0.0102 -82.43 <0.0001
 LnSlope    -0.4033 0.0087 -46.09 <0.0001
```

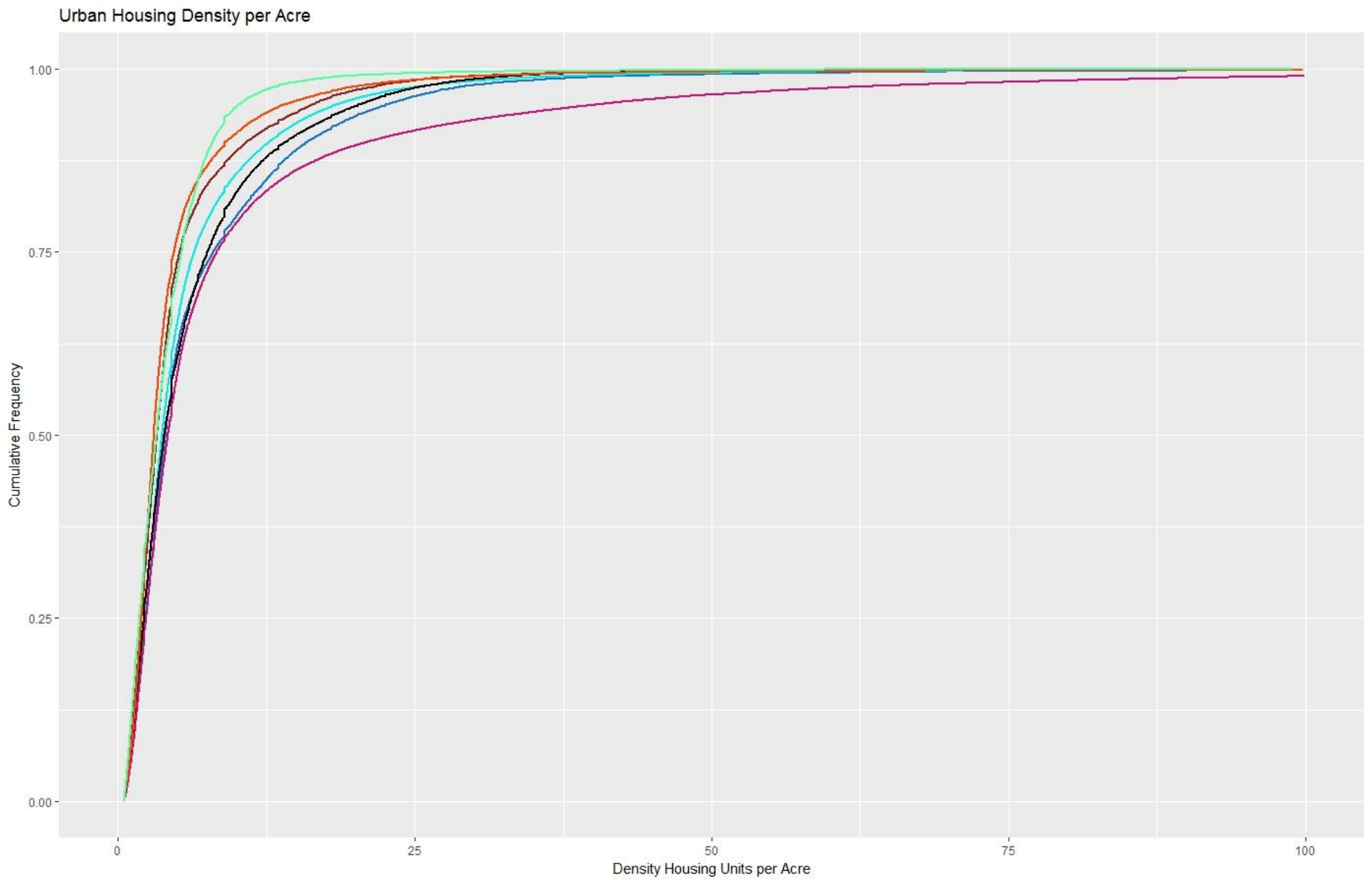
USGS

R^2 Values for Logistic Regressions

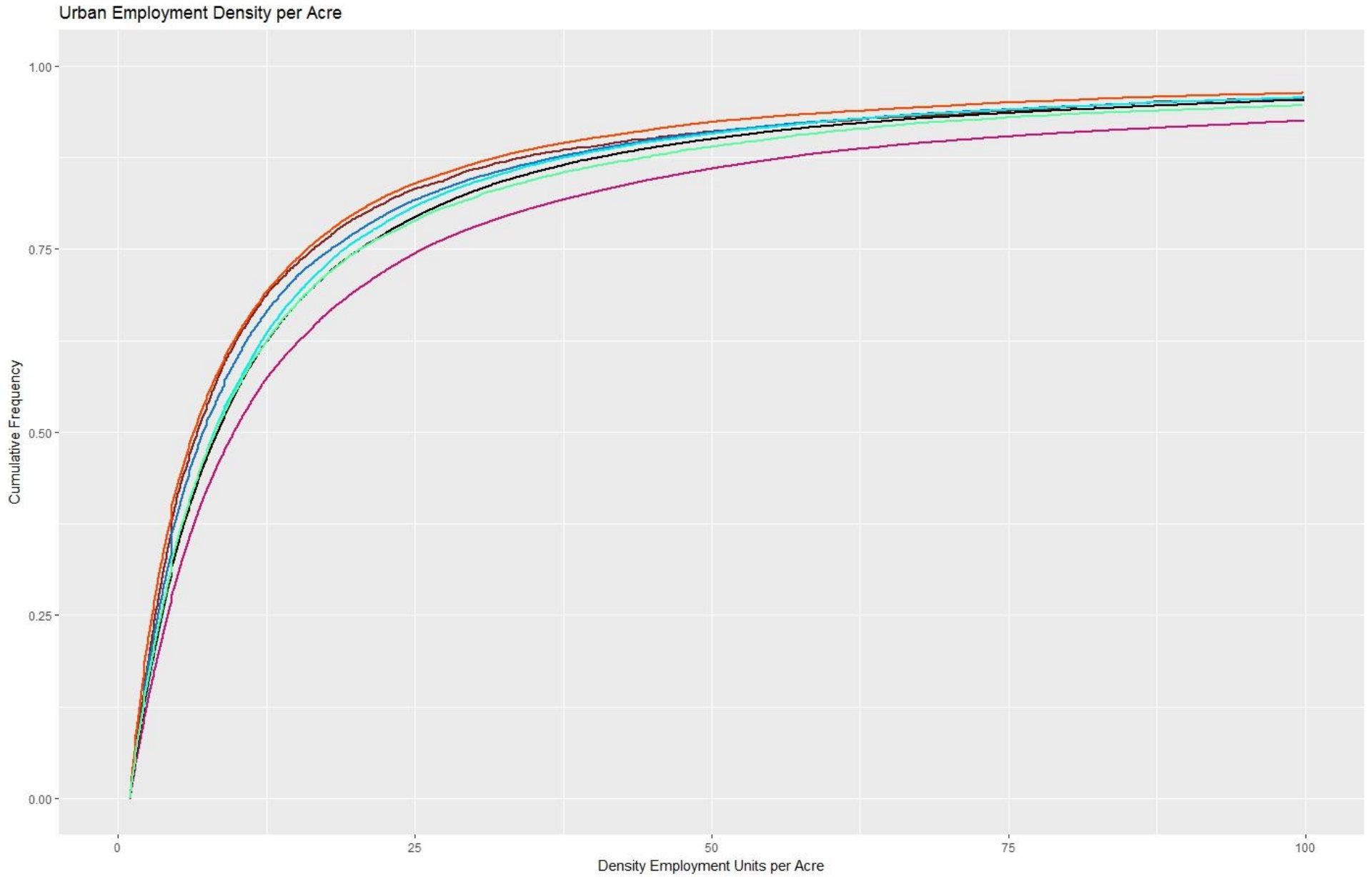
State	Residential	Commercial
Delaware	0.766	0.555
District of Columbia	n/a	n/a
Maryland	0.778	0.718
New York	0.871	0.867
Pennsylvania	0.835	0.821
Virginia	0.901	0.869
West Virginia	0.908	0.921

USGS


Maryland Zoning Density Frequency Distribution (du/acre)
Cumulative Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
Households per Acre


Urban Housing Density per Acre
1.00
0.75
0.50
0.25
0.00
Cumulative Frequency
0
25
50
75
100
Density Housing Units per Acre

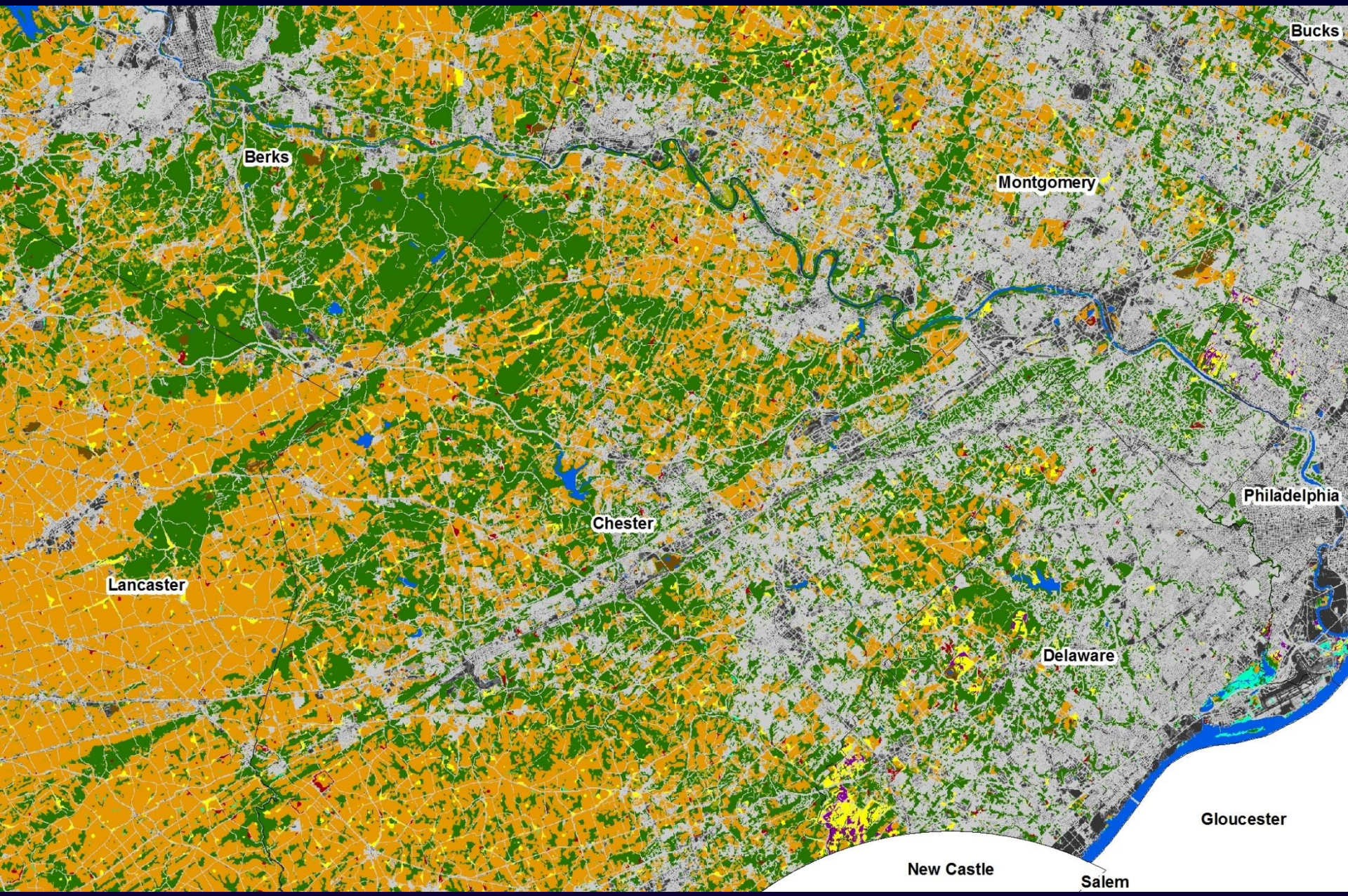
USGS


Urban Employment Density per Acre
1.00
0.75
0.50
0.25
0.00
Cumulative Frequency
0
25
50
75
100
Density Employment Units per Acre

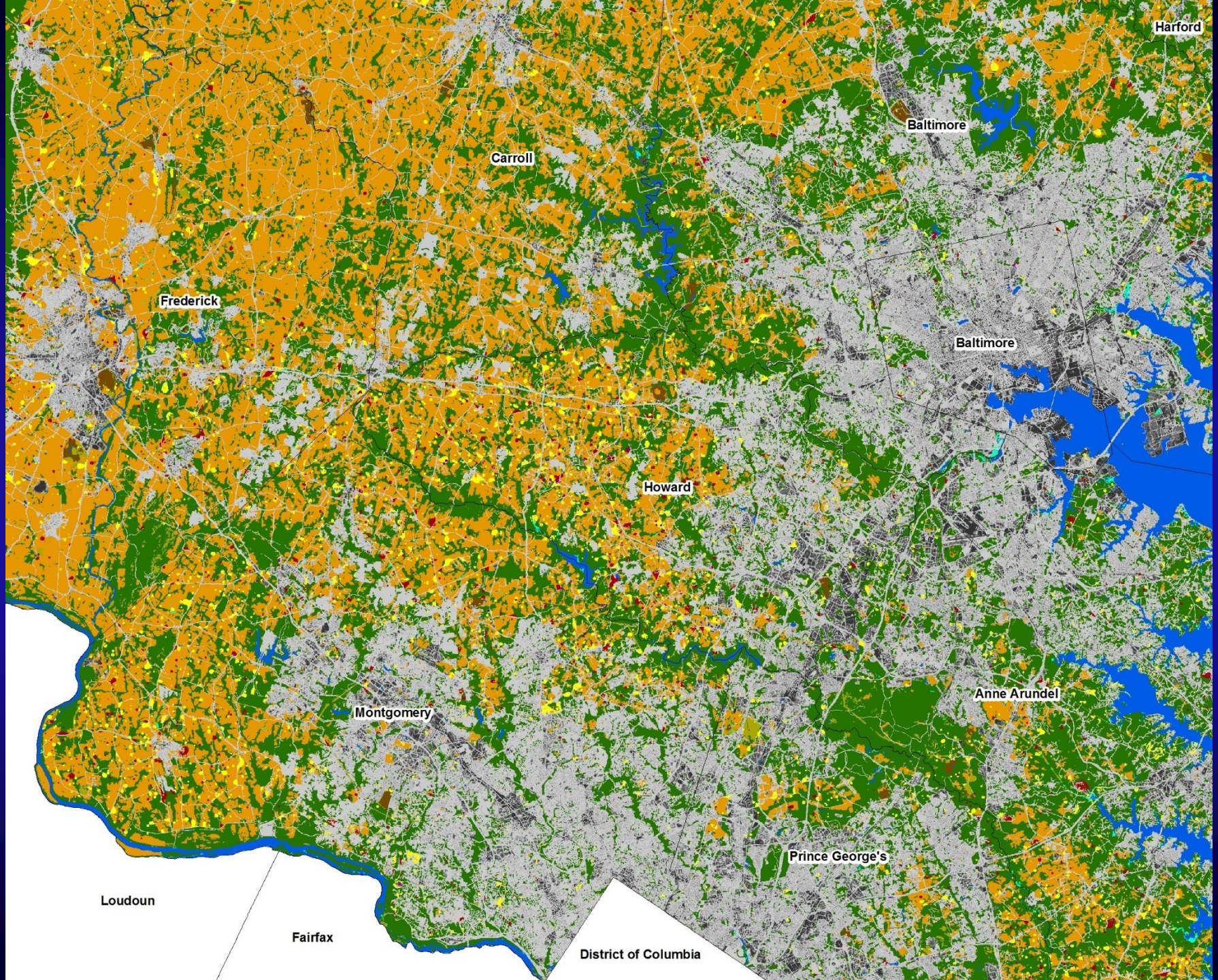
USGS

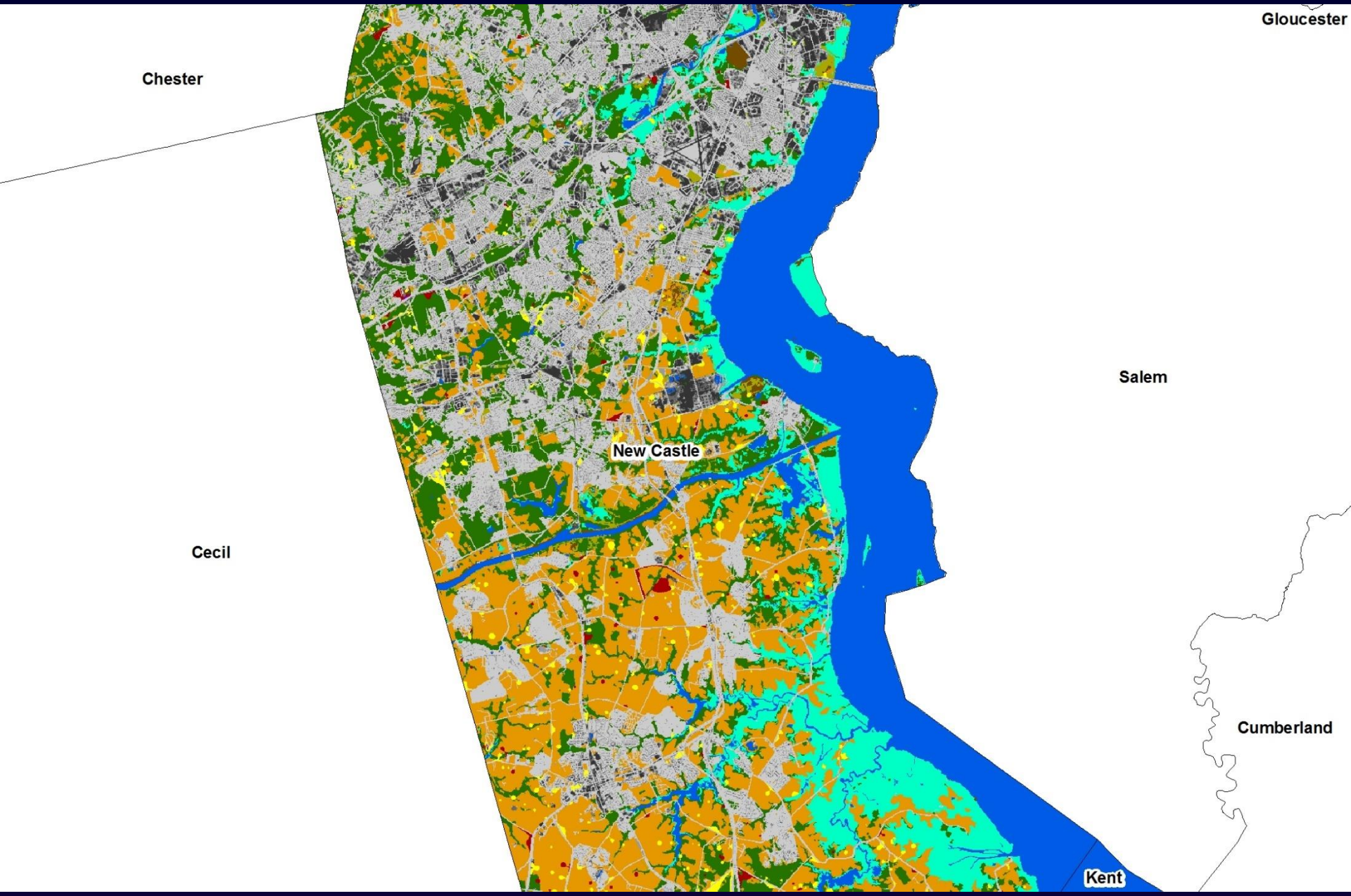
Chesapeake Bay Future Land Use Scenario Domain


Tompkins
Cortland
Tompkins
Chenango
Broome
Tioga
Susquehanna
Bradford

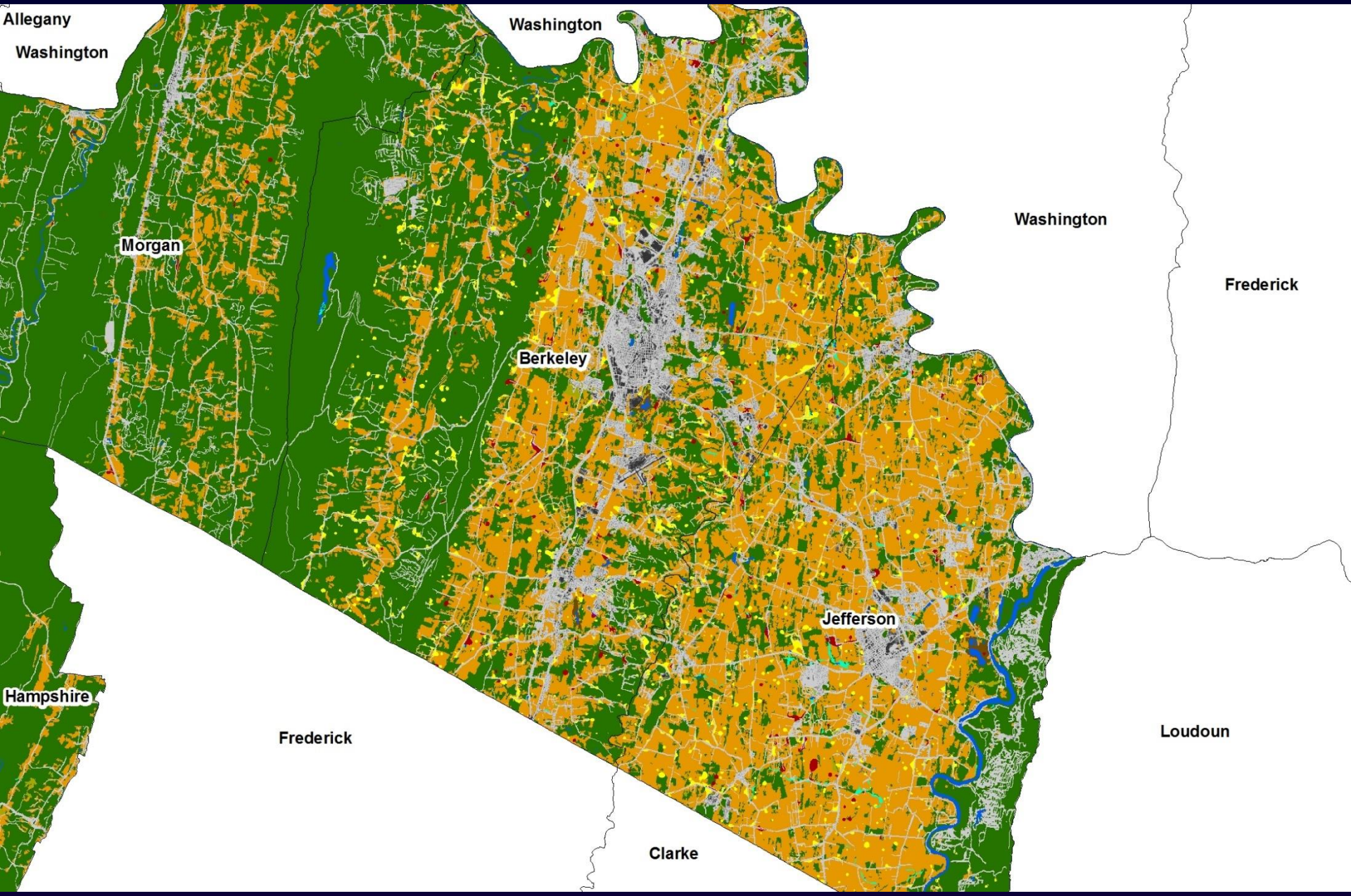

Bucks
Berks
Montgomery
Philadelphia
Chester
Lancaster
Delaware
Gloucester
New Castle
Salem

USGS

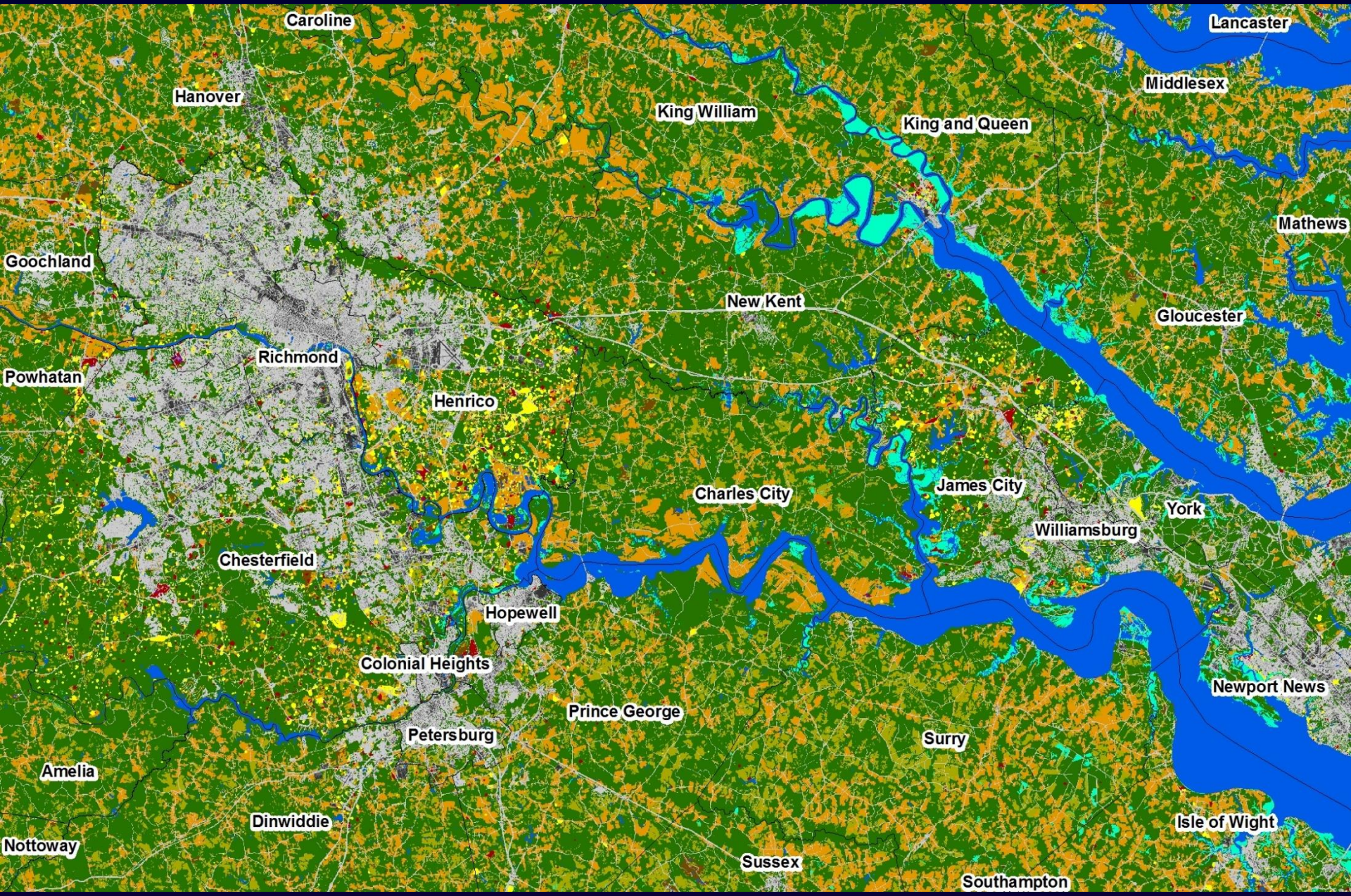

Harford
Baltimore
Carroll
Frederick
Baltimore
Howard
Anne Arundel
Montgomery
Prince George's
Loudoun
Fairfax
District of Columbia


Chester
Gloucester
Salem
New Castle
Cecil
Cumberland
Kent

USGS


Allegany
Washington
Washington
Washington
Morgan
Berkeley
Frederick
Jefferson
Hampshire
Frederick
Clarke
Loudoun

USGS


Caroline
Lancaster
Hanover
Middlesex
King William
King and Queen
Mathews
Goochland
New Kent
Gloucester
Richmond
Powhatan
Henrico
Charles City
James City
York
Williamsburg
Chesterfield
Hopewell
Colonial Heights
Newport News
Prince George
Petersburg
Surry
Amelia
Dinwiddie
Isle of Wight
Nottoway
Sussex
Southampton

USGS

Modeling: Next Steps

1. Regionalize regression variables

2. Add new regression variables such as distance to all roads and travel time to: regional employment centers, waterbodies, or public/protected lands.

3. Incorporate Phase 6 Land Use (currently using 2011 NLCD).

4. Aggregate and reallocate demand by commuter shed; compare with county-level controls

5. Post raster outputs and NHD+ aggregates on Phase 6 Land Use Viewer website to solicit rapid feedback from LUWG on model runs.

6. Continue collection of zoning, permit, and/or comp plan data through May 31, 2017.

7. Organize joint LGAC/LUWG workshop to ensure future scenarios are plausible and useful for informing local government decisions.

USGS

Alternative Futures Production Schedule

Schedule	Deliverable / Decision
End of April 2017	"Historical Trends" Scenario results available. LUWG works to develop Alternative Future Scenarios.
May 31 2017	Deadline for receipt of zoning, planning, and/or permit data to be incorporated into the "Current Policy" Scenario. Refinement of "Historical Trends" scenario.
June 7, 2017 LGAC/LUWG Forum	Joint LUWG-LGAC forum on future scenarios. Finalization of Alternative Future Scenarios. WQGIT invited!
July (TBD) LUWG Call	Results of "Historical Trends", "Current Policy", and alternative future scenarios presented to LUWG.
July 2017	LUWG and WQGIT review scenarios. Issues identified during the review are resolved.
Mid-August 2017	Draft final future scenario results available.
September 6, 2017	LUWG approves draft final future scenarios.
September 11, 2017	WQGIT approves draft final future scenarios.
Early October 2017	Management Board approves draft final future scenarios.
Late October 2017	Principal's Staff Committee approves draft final future scenarios.

USGS