# Dasymetric Mapping: A Critical Geospatial Technique for Public Health Research

**Foster S, Dent A, Rutledge R, Graham S, Purcell N**

**ESRI Health GIS Conference**

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Agency for Toxic Substances and Disease Registry

Geospatial Research, Analysis, and Services Program (GRASP), Division of Health Studies

ATSDR

# Presentation Overview

- **What is dasymetric mapping?**
- **Challenges of dasymetric mapping**
- **Dasymetric mapping of States in HHS Region IV**
- **Public health application of dasymetric mapping**
- **Next steps**

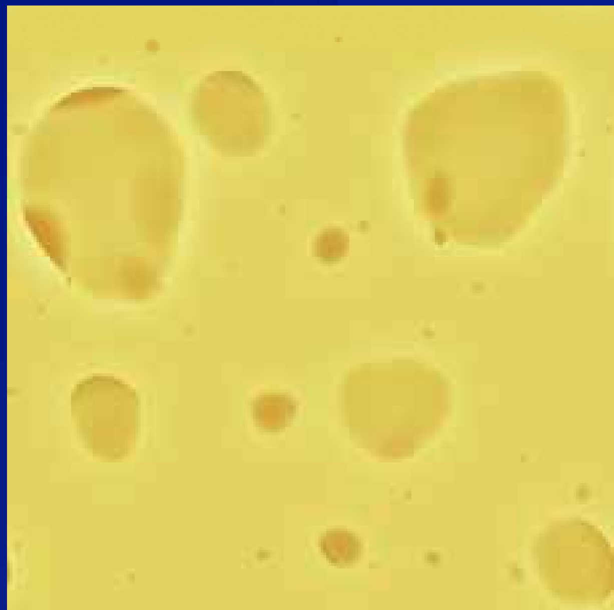
# What Is Dasymetric Mapping?

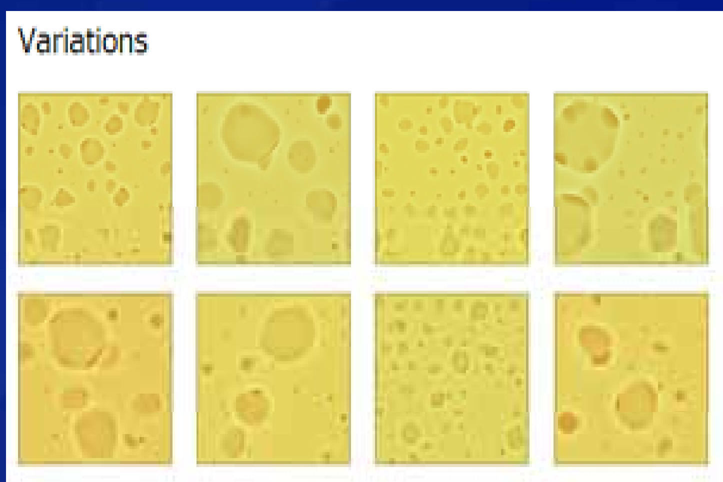
*Illustration Credit & Copyright: Lynette Cook

# What Is Dasymetric Mapping?

**Monticello Dam, California**

stumbles.org.uk/.../Kimberley_Big_Hole_1.jpg




Variations

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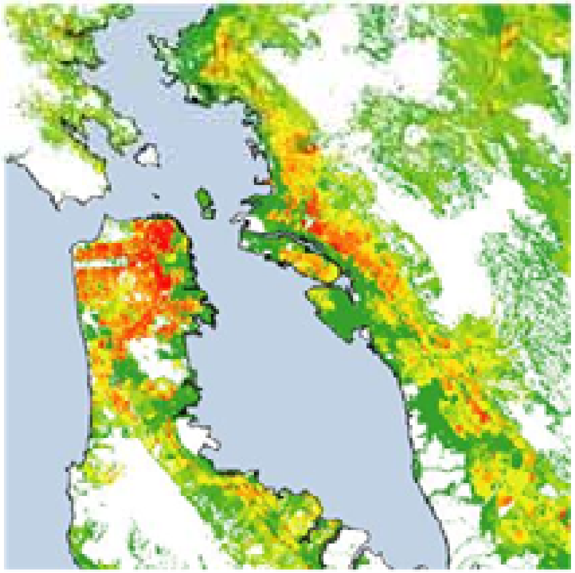
**USGS Western Region Geography**

## Population Density of the San Francisco Bay Area

Overview | Methods | Papers/Abstracts | Data/Image Download | Links/Related Research | Contacts



**Problem:** Human population distributions are commonly displayed using decennial census data. However, these data are aggregates of geographic units (census tracts or block groups) whose boundaries do not always reflect the natural distribution of human populations. A dasymetric mapping technique is one potential solution for mapping population density relative to residential land-use. Dasymetric mapping depicts quantitative areal data using boundaries that divide the area into zones of relative homogeneity with the purpose of better portraying the population distribution.

**Objective:** The San Francisco Bay region's population has grown from approximately 6 million inhabitants in 1990 to 6.8 million inhabitants in the year 2000, a 12% increase. Spatial analysis of the nine-county region is necessary in order to conceptualize urban growth patterns essential for land-use planning and urban-growth modeling. We are developing a method for generating a surface-based representation of demographic data using dasymetric mapping techniques. Our objectives are to (1) use the USGS National Land Cover Datasets for 1992 and 2001 to classify homogeneous zones of high-intensity residential, low-intensity residential, non-urban land-cover; (2) use other information such as slope, land ownership, and transportation to exclude uninhabited areas; (3) create a 30-meter surface grid of population density based on the relative difference in population densities among the urbanization classes and the percentage of total area of each census-block-group occupied by urbanization classes; and (4) visually and statistically represent the population-density results for the region for 1990 and 2000 with static maps and raw, downloadable data.

**Future Work:** The dasymetric mapping technique that we have developed can be easily applied to other regions. Currently, daytime/nighttime populations are being estimated for the Oregon Coast, for emergency response in the event of a Tsunami.

## Dasymetric estimation of population density and areal interpolation of census data.

**Cartography and Geographic Information Science** | April 01, 2004 | Holt, James B.; Lo, C.P.; Hodler, Thomas W.

Introduction

The purpose of this paper is to discuss a dasymetric metho
geographic information system (GIS) and remotely sensed s
dasymetrically derived population densities for areal interpol
of these techniques will be presented from the metropolitan
through 2000.

Population mapping generally has two purposes–to cartogra
population across an area of interest and to derive quantitati
subsequent spatial analytical modeling tasks (Langford 9003

## Generating Surface Models of Population Using Dasymetric Mapping*

Jeremy Mennis
*University of Colorado*

Aggregated demographic datasets are associated with analytical and cartographic
arbitrary nature of areal unit partitioning. This article describes a methodology for ge
representation of population that mitigates these problems. This methodology uses d
incorporates areal weighting and empirical sampling techniques to assess the relations
ancillary data and population distribution. As a demonstration, a 100-meter-resoluti
generated from U.S. Census block group data for the southeast Pennsylvania region. I
urban land-cover data serve as ancillary data in the dasymetric mapping. **Key Wo**
**dasymetric mapping, population data, surface modeling.**

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Initial submission, November 2001; revised submission, June 2002; final acceptan
Published by Blackwell Publishing, 350 Main Street, Malden, MA 02148, and 9600 Garsington

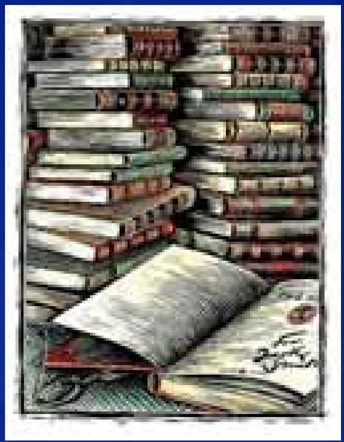
## Dasymetric Mapping and Areal Interpolation: Implementation and Evaluation.

**Cartography and Geographic Information Science** | April 01, 2001 | Eicher, Cory L.; Brewer, Cynthia A. |

Introduction

A dasymetric map depicts quantitative areal data using boundaries that divide the mapped area into zones of relative homogeneity with the purpose of best portraying the underlying statistical surface. The dasymetric map was conceived as a type of thematic map during the early to mid nineteenth century, the formative years of modern thematic cartography. During their early development, the demand for both dasymetric and choropleth maps was driven by interest in population mapping (McCleary 1969, 1984). By 1900, dasymetric and choropleth mapping methods became more clearly differentiated, with the latter becoming overwhelmingly popular in modern cartography and for general use outside the discipline. In contrast, dasymetric mapping has remained relatively unknown even to most geographers. Consistent with their original purpose, dasymetric maps of population are still the most common type found today.

Although dasymetric maps are closely related to choropleth maps, they differ in several ways. First, zonal boundaries on dasymetric maps are based on sharp changes in the statistical surface being mapped, while zonal boundaries on choropleth maps demarcate enumeration units established for more general purposes



# Dasymetric Analysis

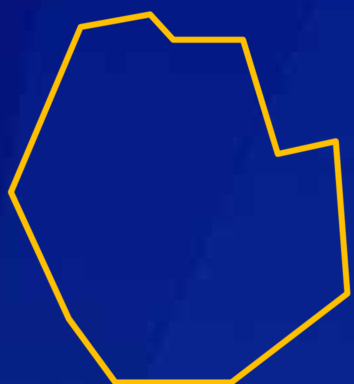
- Dasymetric analysis is a method to disaggregate data to finer scales through the integration of ancillary data.*

- Particularly appropriate for population density

- Reduce generalization of area

*Adapted from: Steiner P, Paulus G. "Dasymetric mapping for public health planning". 10th AGILE International Conference on Geographic Information Science 2007.

# Dasymetric Mapping: Nuts & Bolts

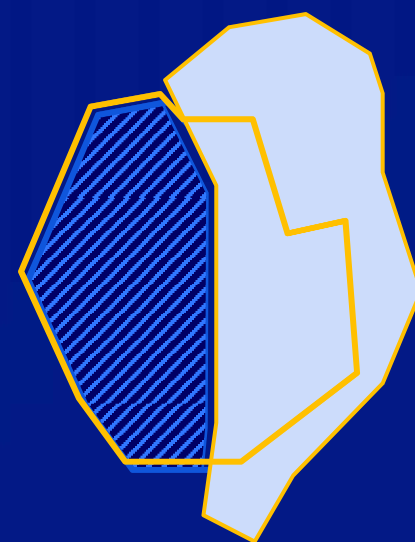


**Source Data**
Census Tract A
Area: 100 square miles
Population: 200
Population Density:
2 persons/sq. mile

+

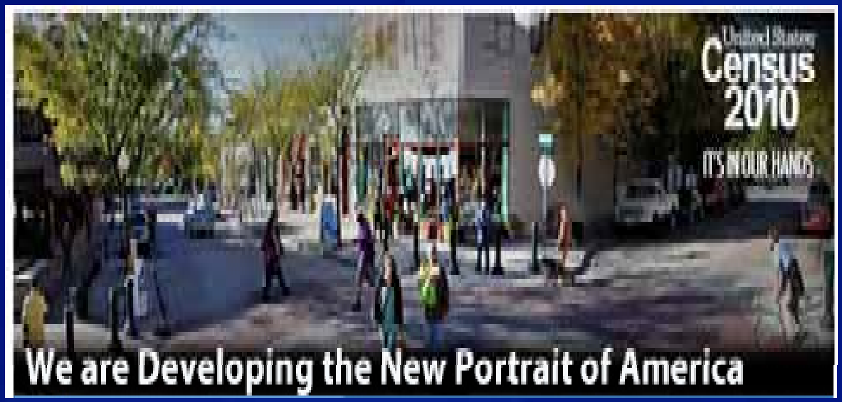
**Ancillary Data**
Water Polygon
Area: 85 square miles

=



**Result**
Inhabited Area, Census Tract A
Area: 50 square miles
Population: 200
Population Density:
4 persons/sq. mile

# Dasymetric Mapping: Data Sources




- US Census Data, Block level, 2000
- Ancillary data
  - Interstates
  - Water bodies
- Additional ancillary data
  - Parks
  - Recreational facilities
  - Federal lands

# Dasymetric Mapping Challenges

- Availability of polygon data
- Accuracy of polygon data borders
- Populated ancillary areas?


*neilperkin.typepad.com/.../2008/04/22/stop.jpg

# Boundary Issues of Polygon Data

Figure 1

Figure 2

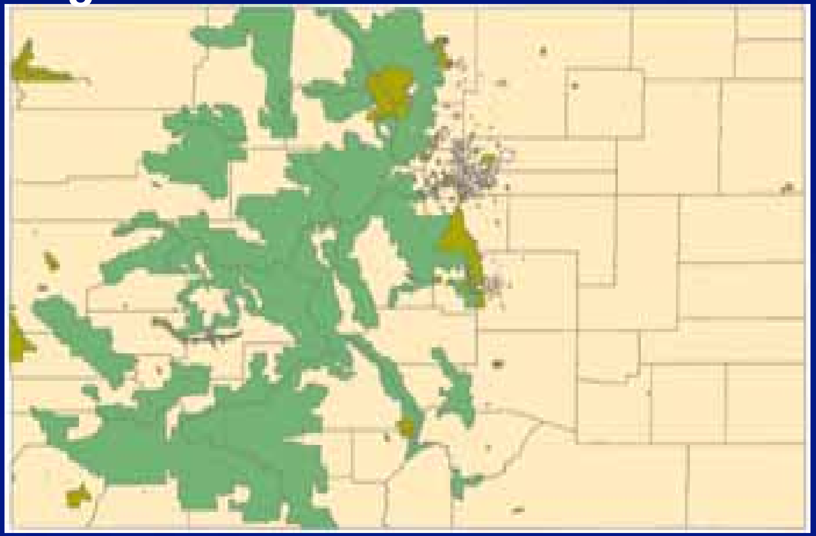


Figure 3

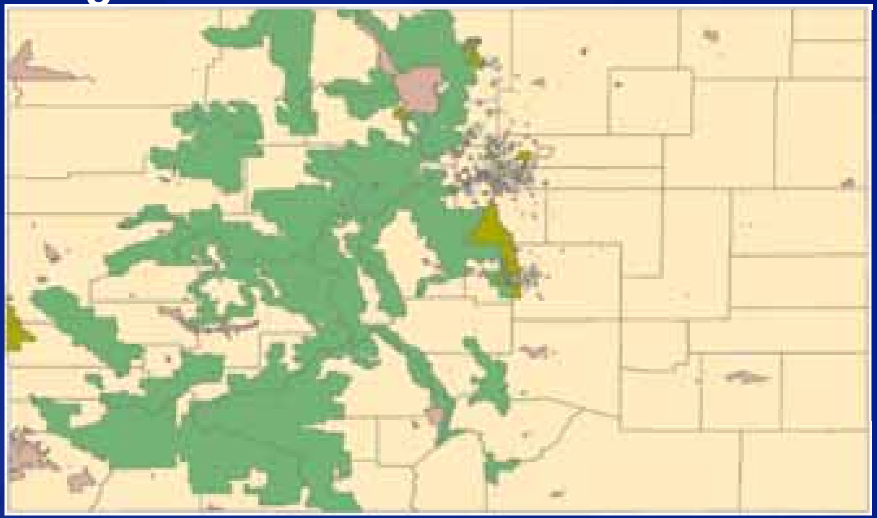
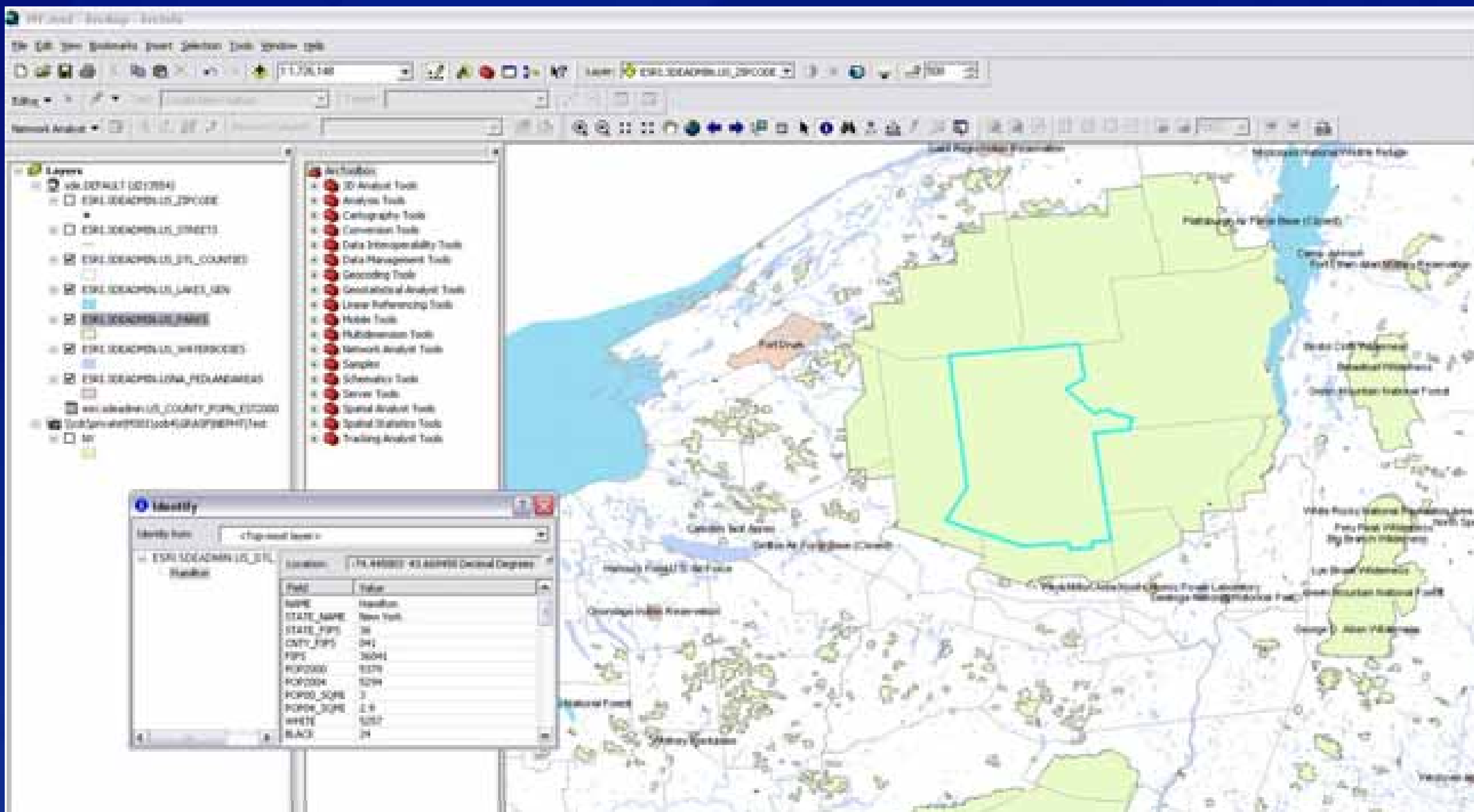


Figure 4

# Populated Parks



# Methods

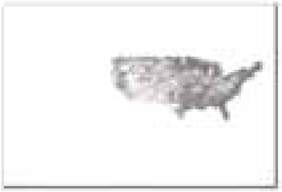
- HHS Region IV
- U.S Census 2000 block data
- Remove blocks with zero populations
- ESRI polygons of areas of assumed zero populations
  - Interstates
  - Water bodies

# Data Sources for Bodies of Water

## US_WATERBODIES

SDE Feature Class

Description | Spatial | Attributes



**Keywords**

**Theme:** polygon, lakes, reservoirs, lagoons, hydrography, inlandWaters

**Place:** United States

**Temporal:** 2004

**Description**

Abstract

U.S. Water Bodies represents the major lakes, reservoirs, large rivers, lagoons, and estuaries in the United States.

Purpose

U.S. Water Bodies provides a database of areal water features that identifies the water bodies or reaches that comprise the surface water drainage system of United States.

## USNA_WATER_AREAS

SDE Feature Class

Description | Spatial | Attributes

**Keywords**

**Theme:** polygon, hydrography, water, bays, glaciers, lakes, reservoirs, streams, swamps, inlandWaters

**Place:** United States, Puerto Rico, U.S. Virgin Islands

**Temporal:** 1995, 2002

**Description**

Abstract

U.S. National Atlas Water Feature Areas represents the water feature areas (for example, bays, glaciers, lakes, and swamps) of the United States.

Purpose

U.S. National Atlas Water Feature Areas provides the water feature areas for geographic display and analysis at regional and national levels.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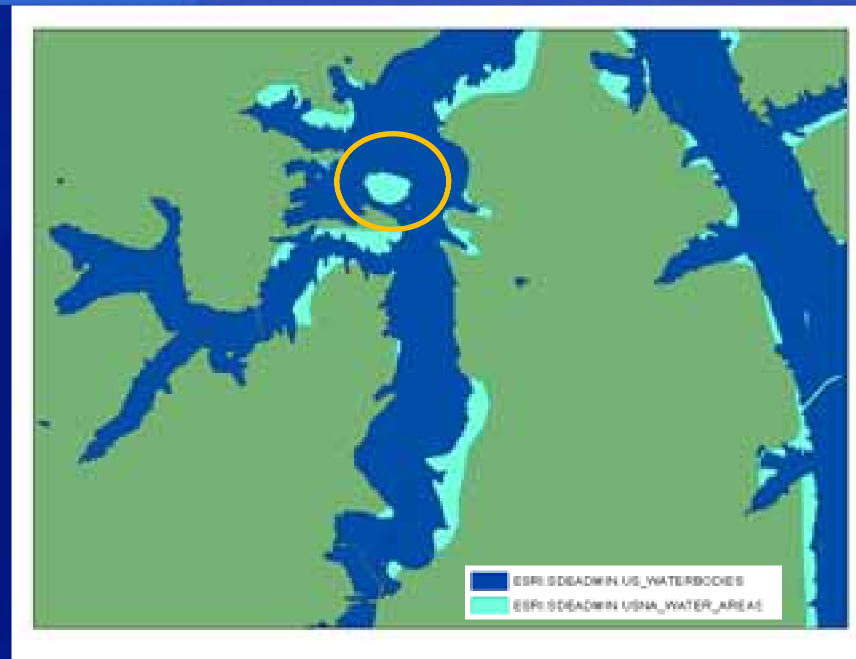

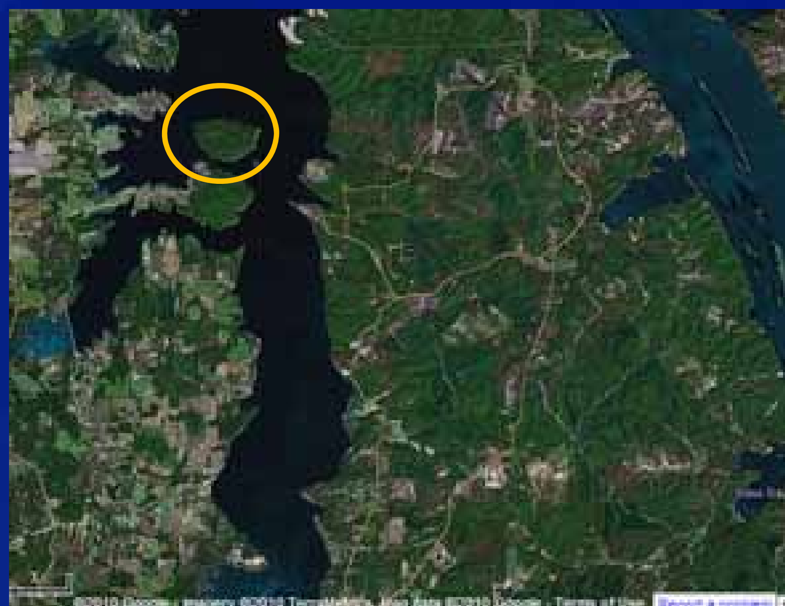
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# Interstate Highway standards

**Standards for Interstate Highways** in the United States are defined by the American Association of State Highway and Transportation Officials (AASHTO) in the publication *A Policy on Design Standards - Interstate System*. For a certain highway to be considered an Interstate, it must meet these construction requirements or obtain a waiver from the Federal Highway Administration.

## Standards

These standards are, as of July 2007, as follows:

- **Controlled access.** All access onto and off the roadway is to be controlled with interchanges and grade separations (including railroad crossings). See List of gaps in Interstate Highways for the few cases that violate this rule. Interchanges should provide full access; ramps are to be designed with the appropriate standards in mind. Minimum interchange spacing should be 1 mi (1.6 km) in urban areas and 3 mi (4.8 km) in rural areas; collector/distributor roads or other configurations that reduce weaving can be used in urban areas to shorten this distance.
  - Access control (from adjacent properties) should extend at least 100 feet (30 m) in urban areas and 300 feet (91 m) in rural areas in each direction along the crossroad from the ramps.
- **Minimum design speed.** Minimum design speed of 75 mph (121 km/h) in rural areas, with 65 mph (105 km/h) acceptable in rolling terrain, and as low as 50 mph (80 km/h) allowed in mountainous and urban areas. However, speed limits as low as 40 mph (64 km/h) are occasionally encountered, generally on pre-existing freeways that were grandfathered into the system.
  - Sight distance, curvature and superelevation according to the current edition of AASHTO's *A Policy on Geometric Design of Highways and Streets* for the design speed.

An Interstate Highway under construction, with both lanes of traffic moved to one side of the roadway

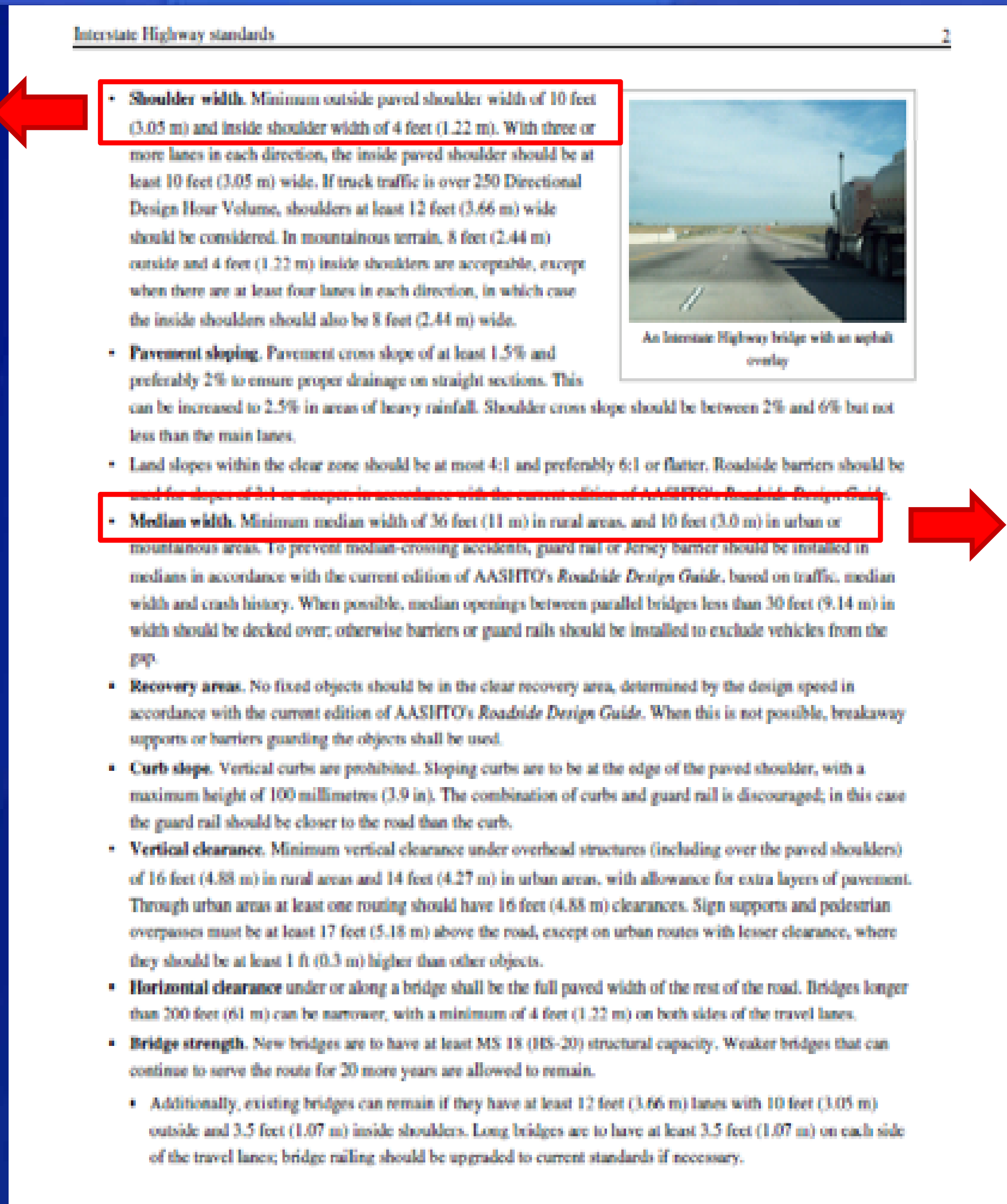
- **Maximum grade.** Maximum grade is determined by a table, with up to 6% allowed in mountainous areas and hilly urban areas.
- **Minimum number of lanes.** At least two lanes in each direction, and more if necessary for an acceptable level of service in the design year, according to the current edition of AASHTO's *A Policy on Geometric Design of Highways and Streets*. Climbing lanes and emergency escape ramps should be provided where appropriate.
- **Minimum lane width.** Minimum lane width of 12 feet (3.66 m).

I-94 in Michigan, showing examples of non-interchange overpass signage in median, upcoming exit signage on right shoulder, a 1950s overpass with height restriction signage, newly installed cable median barrier, and parallel grooved pavement with shoulder rumble strips

4 Lanes * 12 feet = 48 feet

28 feet

10 feet





- **Shoulder width.** Minimum outside paved shoulder width of 10 feet (3.05 m) and inside shoulder width of 4 feet (1.22 m). With three or more lanes in each direction, the inside paved shoulder should be at least 10 feet (3.05 m) wide. If truck traffic is over 250 Directional Design Hour Volume, shoulders at least 12 feet (3.66 m) wide should be considered. In mountainous terrain, 8 feet (2.44 m) outside and 4 feet (1.22 m) inside shoulders are acceptable, except when there are at least four lanes in each direction, in which case the inside shoulders should also be 8 feet (2.44 m) wide.

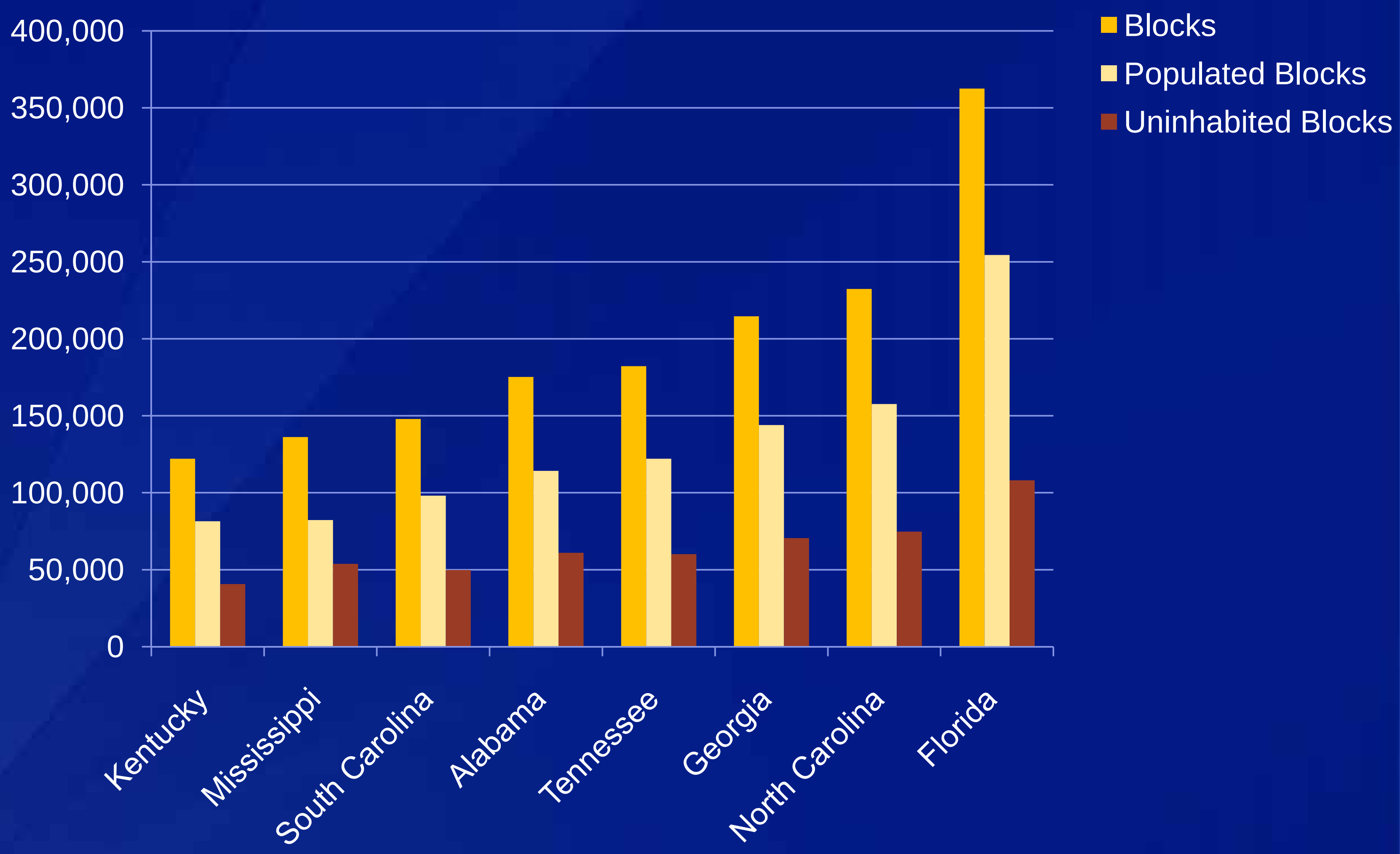
An Interstate Highway bridge with an asphalt overlay

- **Pavement sloping.** Pavement cross slope of at least 1.5% and preferably 2% to ensure proper drainage on straight sections. This can be increased to 2.5% in areas of heavy rainfall. Shoulder cross slope should be between 2% and 6% but not less than the main lanes.
- Land slopes within the clear zone should be at most 4:1 and preferably 6:1 or flatter. Roadside barriers should be used for slopes of 3:1 or steeper, in accordance with the current edition of AASHTO's *Roadside Design Guide*.
- **Median width.** Minimum median width of 36 feet (11 m) in rural areas, and 10 feet (3.0 m) in urban or mountainous areas. To prevent median-crossing accidents, guard rail or Jersey barrier should be installed in medians in accordance with the current edition of AASHTO's *Roadside Design Guide*, based on traffic, median width and crash history. When possible, median openings between parallel bridges less than 30 feet (9.14 m) in width should be decked over; otherwise barriers or guard rails should be installed to exclude vehicles from the gap.
- **Recovery areas.** No fixed objects should be in the clear recovery area, determined by the design speed in accordance with the current edition of AASHTO's *Roadside Design Guide*. When this is not possible, breakaway supports or barriers guarding the objects shall be used.
- **Curb slope.** Vertical curbs are prohibited. Sloping curbs are to be at the edge of the paved shoulder, with a maximum height of 100 millimetres (3.9 in). The combination of curbs and guard rail is discouraged; in this case the guard rail should be closer to the road than the curb.
- **Vertical clearance.** Minimum vertical clearance under overhead structures (including over the paved shoulders) of 16 feet (4.88 m) in rural areas and 14 feet (4.27 m) in urban areas, with allowance for extra layers of pavement. Through urban areas at least one routing should have 16 feet (4.88 m) clearances. Sign supports and pedestrian overpasses must be at least 17 feet (5.18 m) above the road, except on urban routes with lesser clearance, where they should be at least 1 ft (0.3 m) higher than other objects.
- **Horizontal clearance** under or along a bridge shall be the full paved width of the rest of the road. Bridges longer than 200 feet (61 m) can be narrower, with a minimum of 4 feet (1.22 m) on both sides of the travel lanes.
- **Bridge strength.** New bridges are to have at least MS 18 (HS-20) structural capacity. Weaker bridges that can continue to serve the route for 20 more years are allowed to remain.
    - Additionally, existing bridges can remain if they have at least 12 feet (3.66 m) lanes with 10 feet (3.05 m) outside and 3.5 feet (1.07 m) inside shoulders. Long bridges are to have at least 3.5 feet (1.07 m) on each side of the travel lanes; bridge railing should be upgraded to current standards if necessary.

# Methods

- Remove blocks with zero populations per census
- ESRI polygons of areas of assumed zero populations
  - Removed 43 feet buffer around interstates
  - ESRI_US_Waterbodies

# U.S. Census Blocks by State

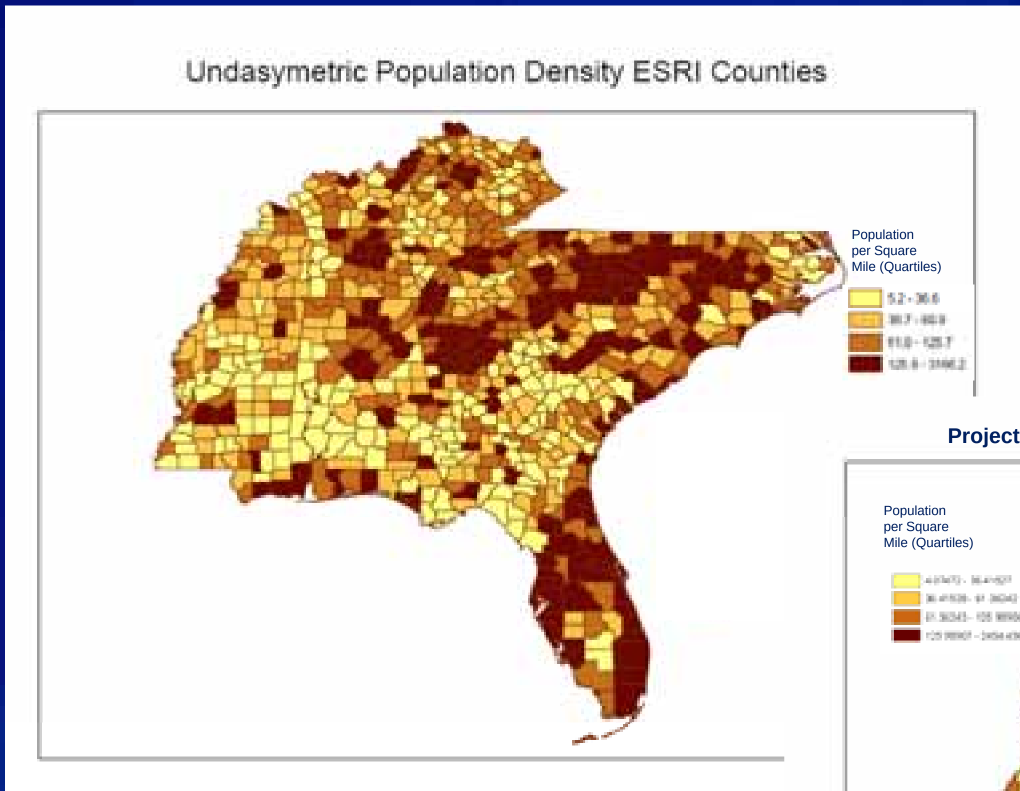


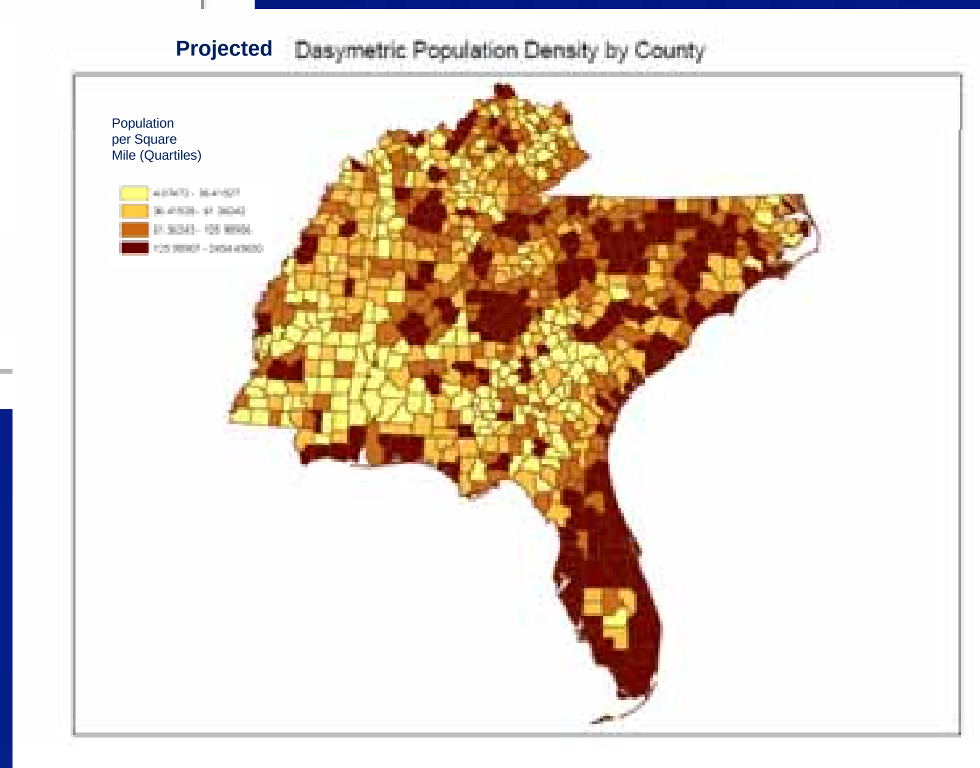
# Effects of Removing Uninhabited Areas on Total Area

| State | Area (sq. mi) | Dasymetric Area (sq. mi) | Area Percent Change |
|---|---|---|---|
| Kentucky | 40423.01 | 36867.3 | -8.8 |
| Tennessee | 42149.4 | 36805 | -12.7 |
| Alabama | 52387.52 | 42723.1 | -18.4 |
| Georgia | 59424.75 | 46815 | -21.2 |
| Mississippi | 48430.19 | 37079 | -23.4 |
| North Carolina | 53861.78 | 40895.8 | -24.1 |
| South Carolina | 32979.12 | 23883.4 | -27.6 |
| Florida | 65754.59 | 32235.7 | -51.0 |
| Total | 395410.4 | 297304.3 | -24.8 |

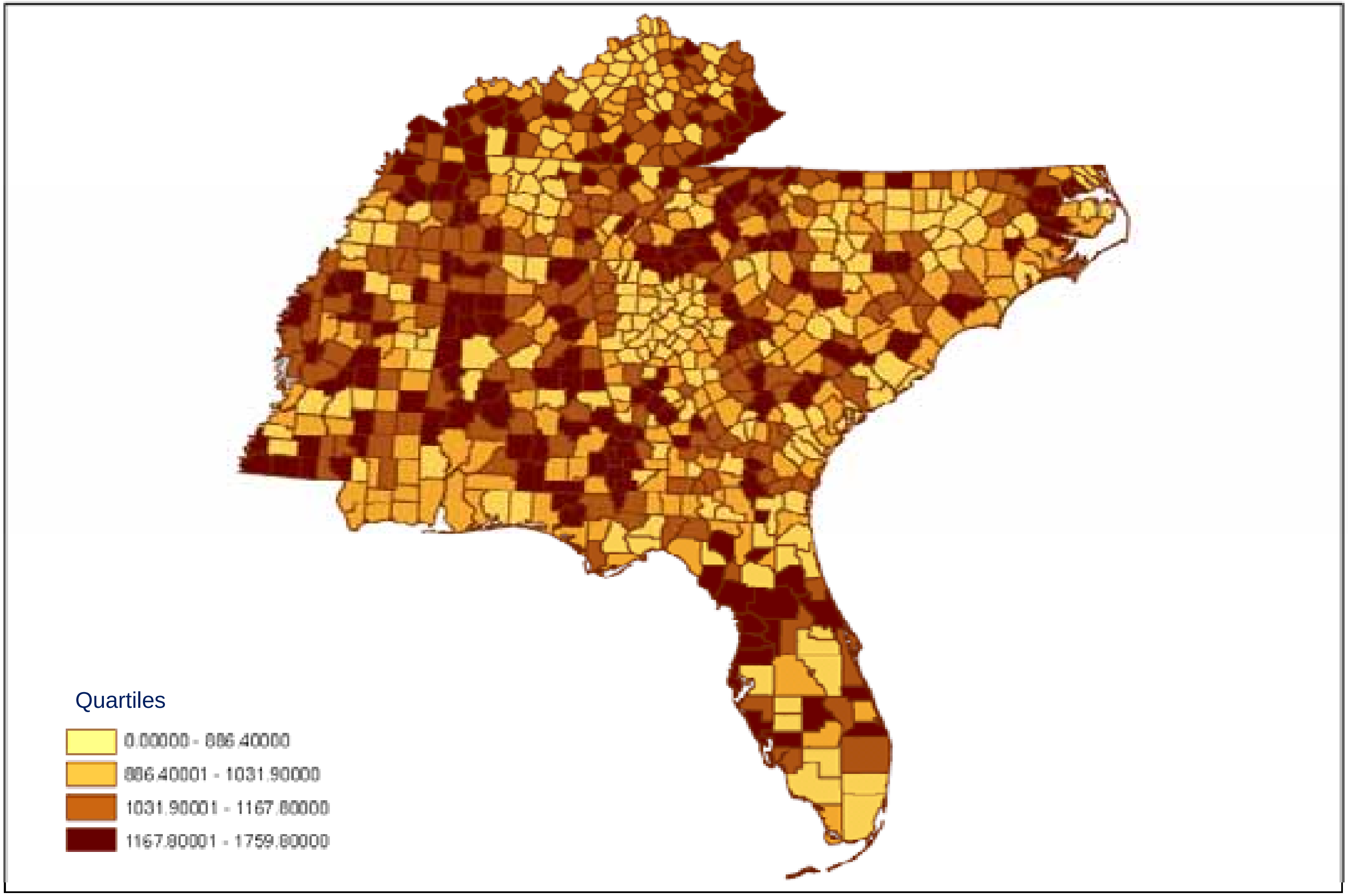
# Effects of Removing Uninhabited Areas on Population Density

| State | Population Density (per sq. mi) | Dasymetric Population Density (per sq. mi) | Population Density Change (sq. mi) | Dasymetric Population Density Percent Change |
|---|---|---|---|---|
| Kentucky | 103 | 112.9 | -9.9 | 9.6 |
| Tennessee | 140.7 | 161.1 | -20.4 | 14.5 |
| Alabama | 84.9 | 104.1 | -19.2 | 22.6 |
| Georgia | 137.8 | 174.9 | -37.1 | 26.9 |
| Mississippi | 58.7 | 76.7 | -18 | 30.6 |
| North Carolina | 149.4 | 196.8 | -47.4 | 31.7 |
| South Carolina | 123.6 | 170.7 | -47.1 | 38.1 |
| Florida | 243.1 | 495.8 | -252.7 | 104.0 |
| Total | 135.7 | 180.5 | -44.8 | 33.0 |

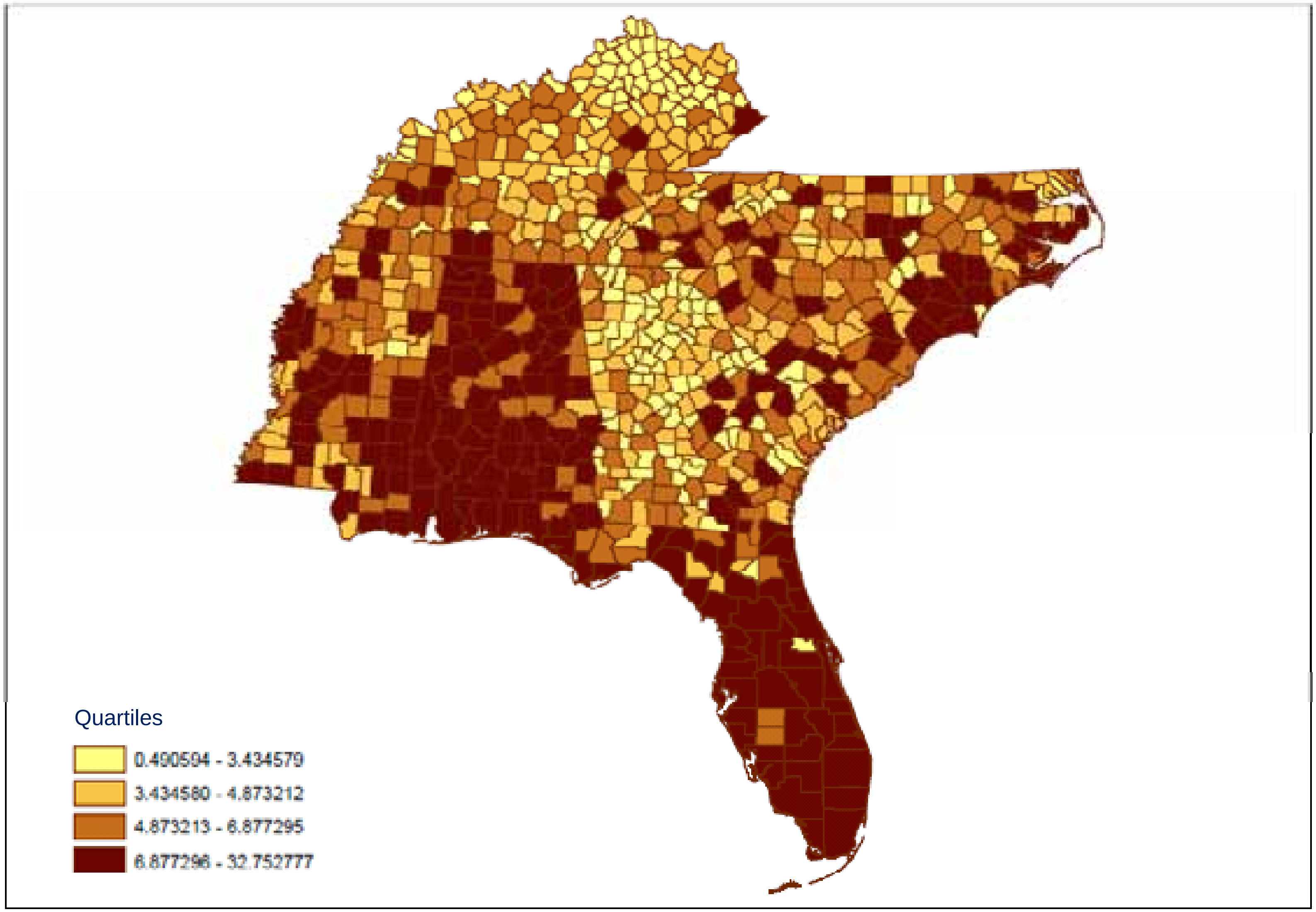

Undasymetric Population Density ESRI Counties
Population
per Square
Mile (Quartiles)

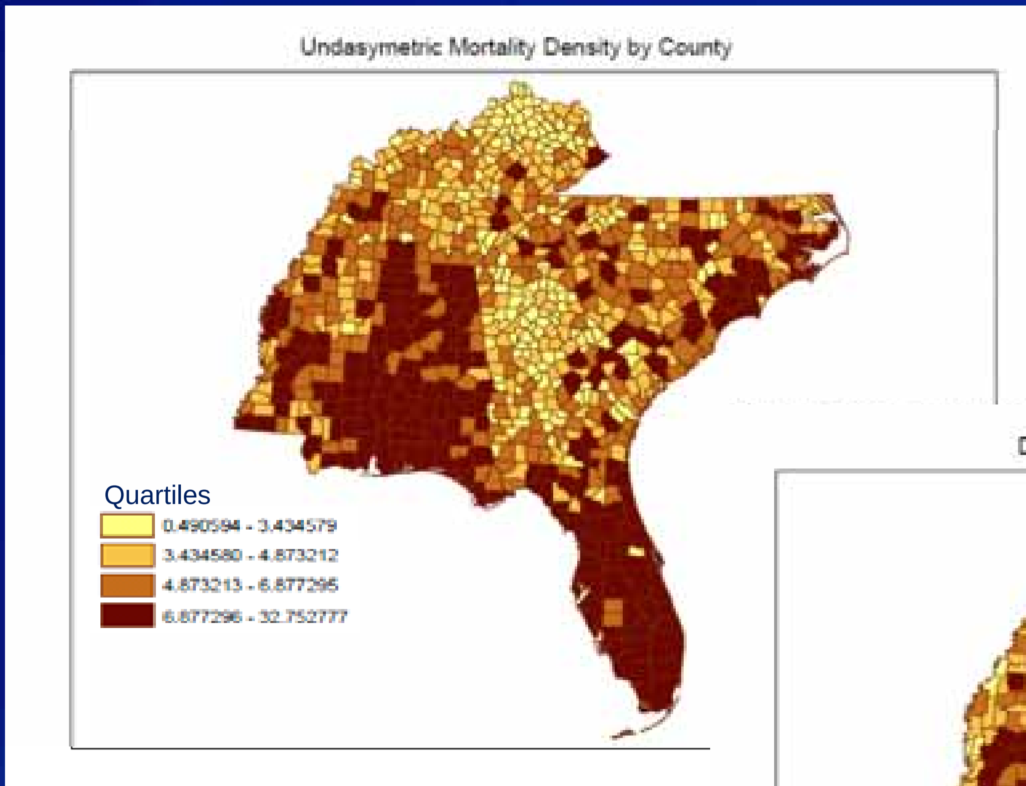

Projected
Dasymetric Population Density by County
Population
per Square
Mile (Quartiles)

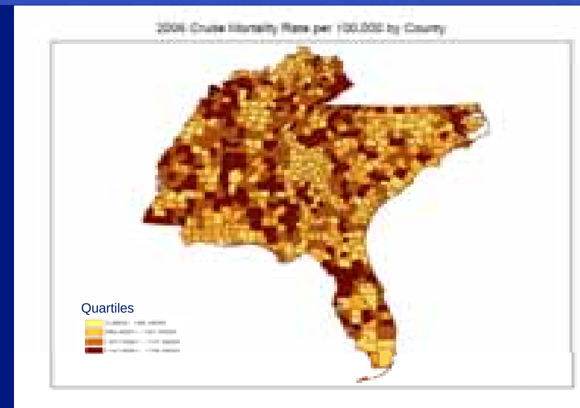
# 2006 Crude Mortality Rate per 100,000 by County

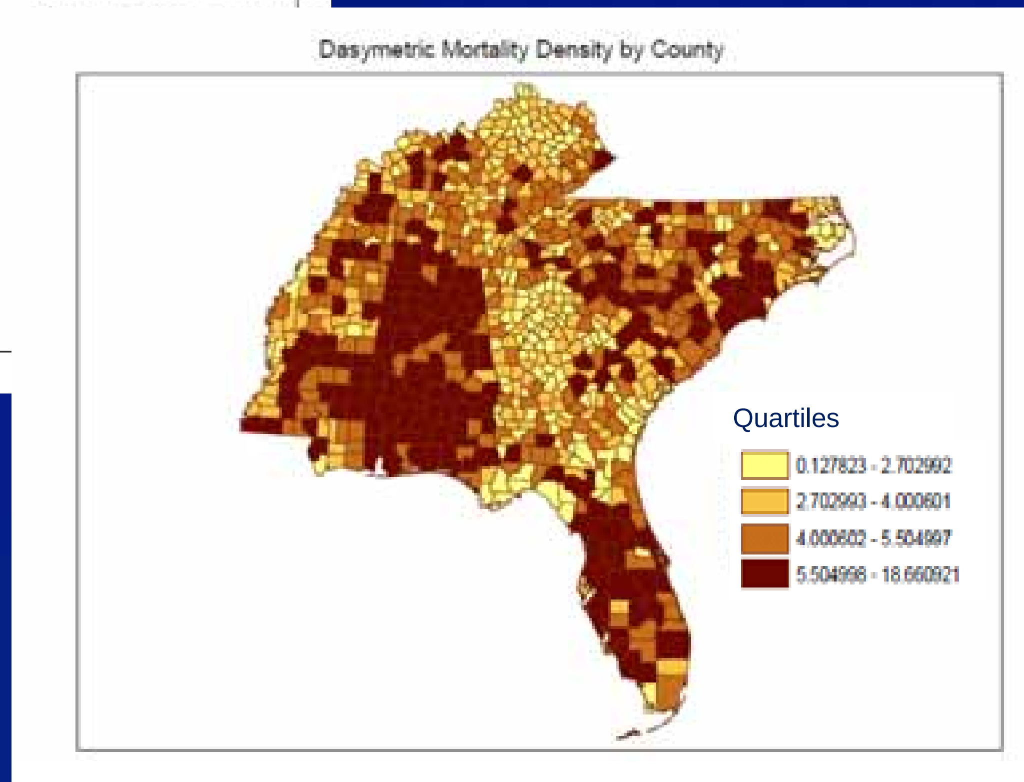


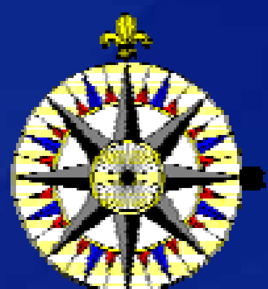
# Undasymetric Mortality Density by County

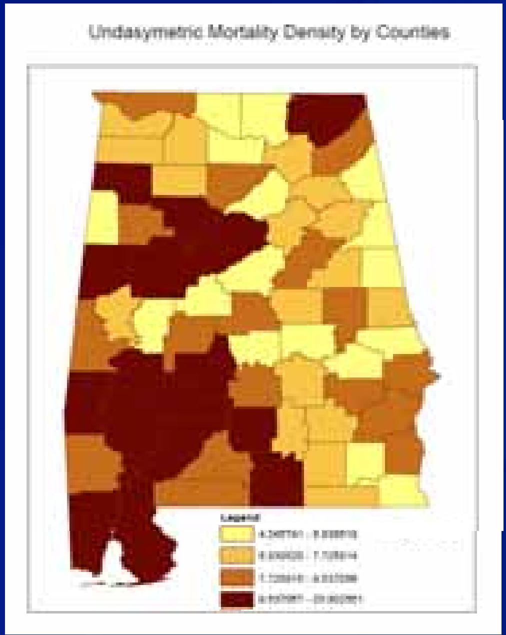


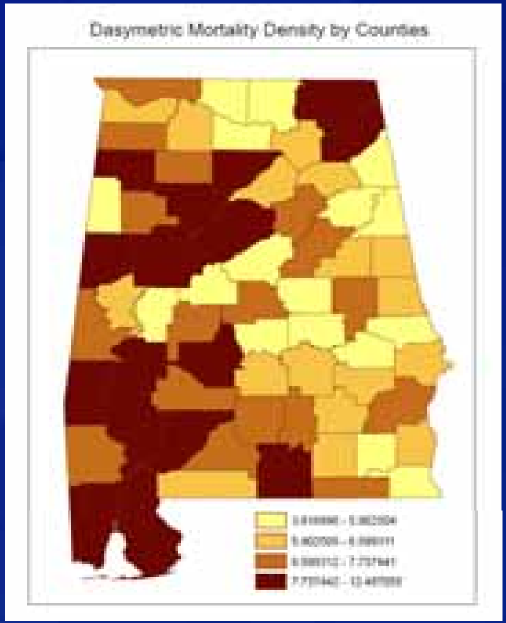

Undasymetric Mortality Density by County
Quartiles
0.490594 - 3.434579
3.434580 - 4.873212
4.873213 - 6.877295
6.877296 - 32.752777


2006 Crude Mortality Rate per 100,000 by County
Quartiles

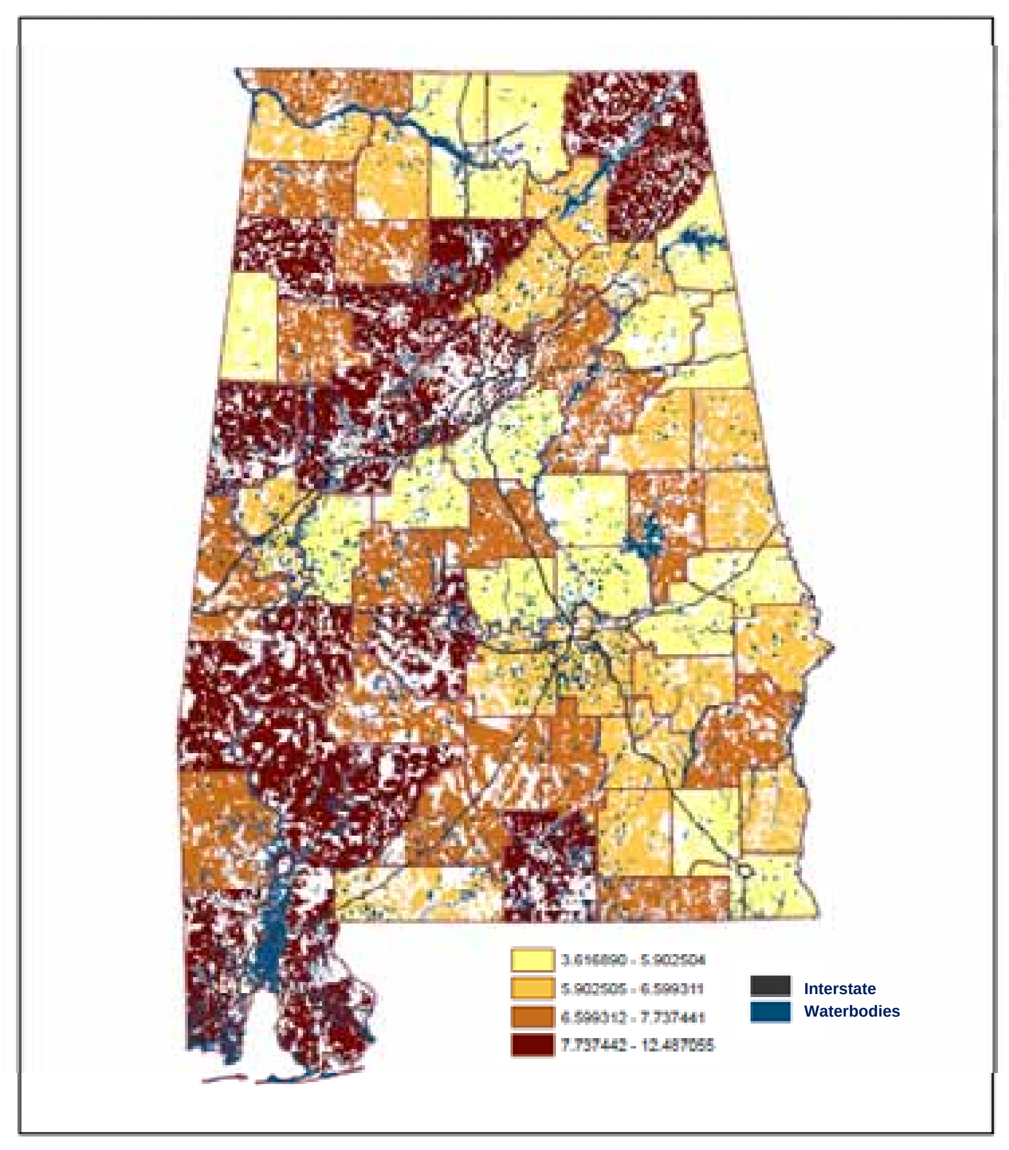

Dasymetric Mortality Density by County
Quartiles
0.127823 - 2.702992
2.702993 - 4.000601
4.000602 - 5.504997
5.504998 - 18.660921






# Dasymetric Mortality Density by County



# Next Steps

- What data sources for other ancillary data polygon boundaries?

- How to deal with populated ancillary data?
  - Aerial imagery
  - Land cover and land use
  - Night time lights

- Smoothing

# Summary

- There are challenges associated with identifying appropriate data sources
- Working at the US Census block level is arduous but results are meaningful
- Continuing this work to expand nationally and to include additional data sources
- Suggest calculation and presentation of public health data aggregated to the county level using dasymetric population densities

# Special Thanks…

**Shannon Graham**

**Nora Purcell**

**Jeff Henry**

**For extraordinary GIS analysis skills and for remaining extraordinarily calm during numerous moments of crisis!!**

## For more information contact:


## Stephanie Foster, MPH, MA

**SLFoster@cdc.gov**

**770.488.3870**


*The findings and conclusions in this presentation have not been formally disseminated by the Agency for Toxic Substances and Disease Registry and should not be construed to represent any agency determination or policy.*