# SEST-6577
# **Geographic Information Systems for Security Studies**
## Lecture 03 (Spatial Analysis and Geoprocessing)

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# Outline

1. Spatial Analysis
   a) spatial queries
   b) measurement
2. Geoprocessing
   a) joining datasets
   b) Modifiable Areal Unit Problem

# Spatial Analysis

**Definition**: spatial analysis

- any method that uses data on objects' *locations* and *attributes*

**Types**

- queries
- measurements
- transformations
- spatial joins
- descriptive summaries
- hypothesis tests

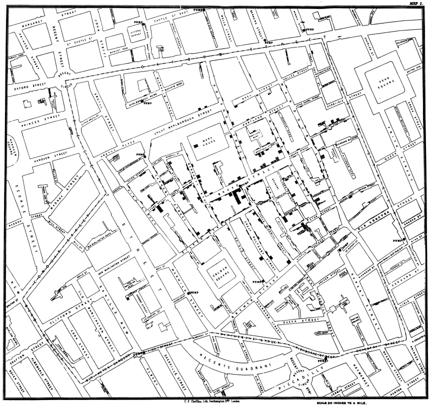


Figure 1: For example, this

# Spatial Queries

## Spatial Queries

- simplest type of spatial analysis
- focus on descriptive information
- requires no changes to dataset

## Examples

- feature identification
  ("which county is this?")
- feature selection
  ("which counties are located in the Midwest?")
- selection by attributes
  ("which are most populous?")
- selection by location
  ("which are closest to the Canadian border?")

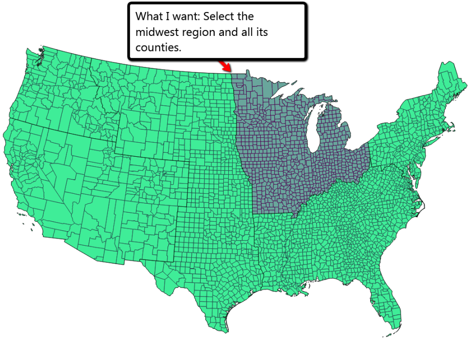
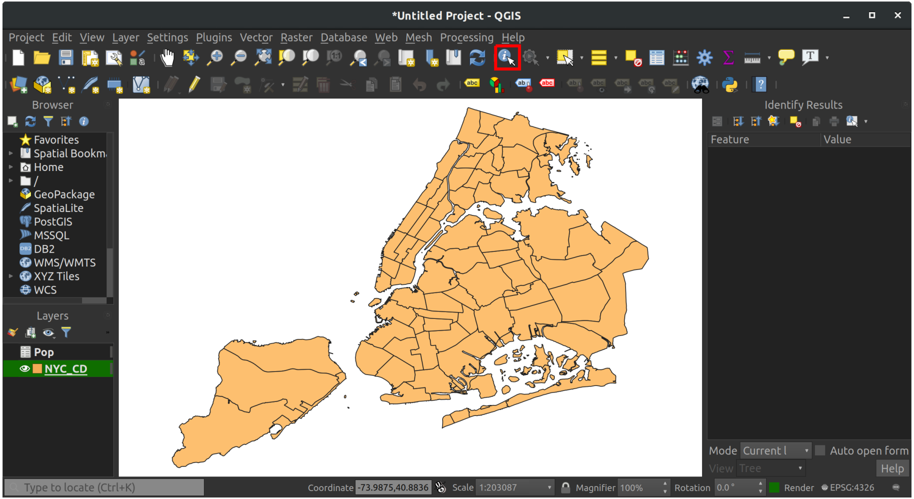
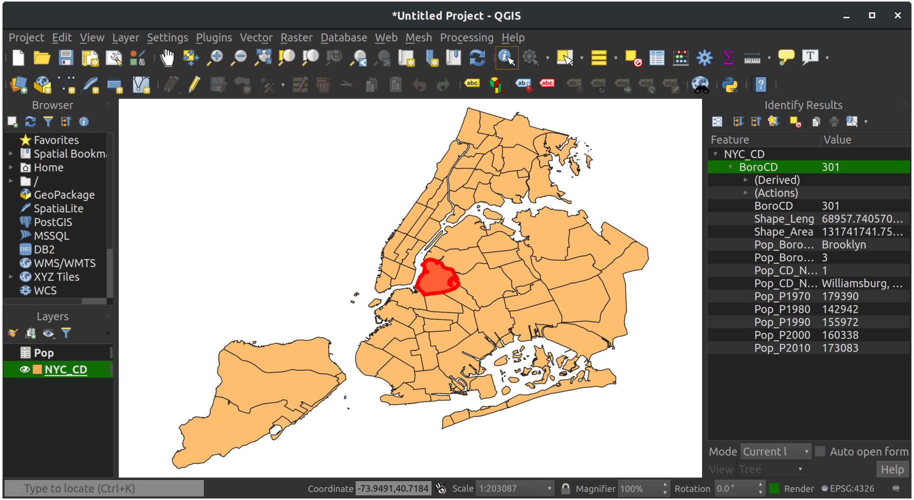



Figure 2: Example of a spatial query

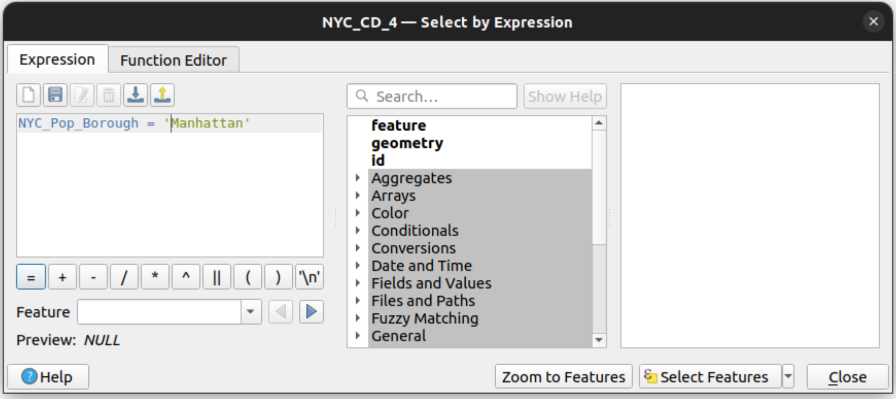



In **QGIS**, you can do a simple query by clicking the `Identify Features` button



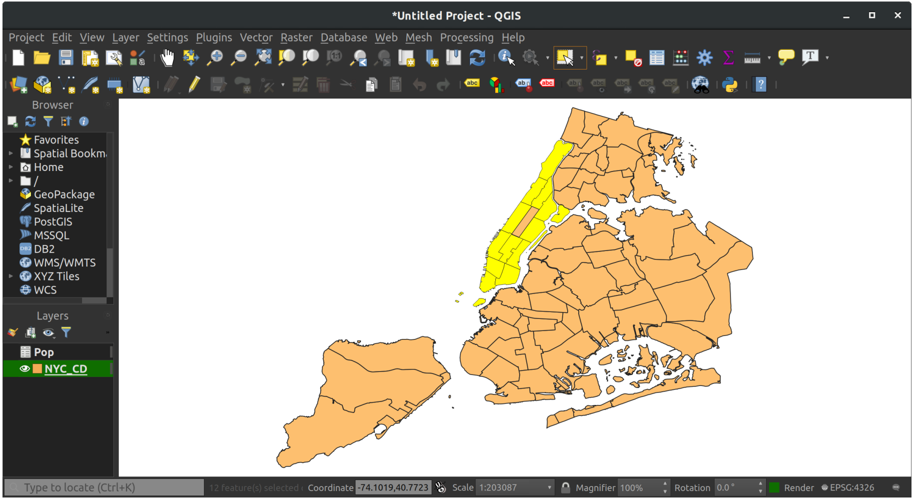

... and clicking on a polygon (or point, line, grid cell)

This polygon represents the Williamsburg, Brooklyn community district

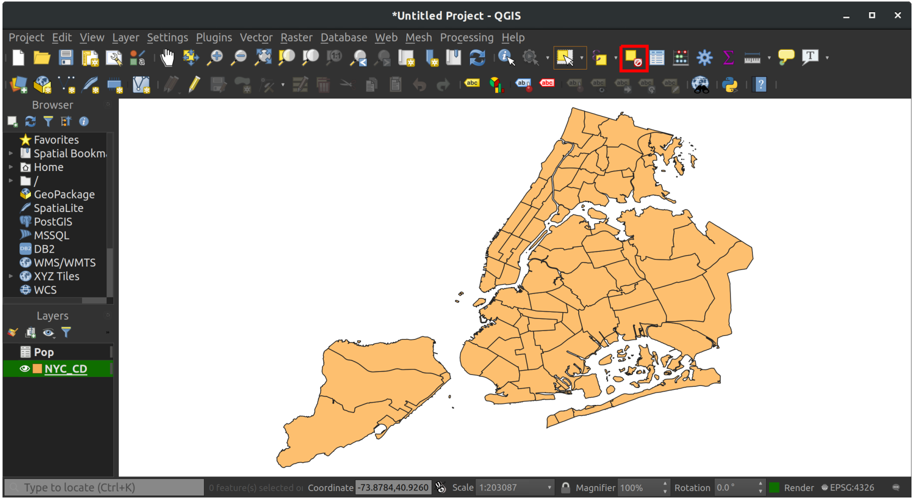



What if we wanted to select all districts in a borough?

- we can do so through the `Select Features by Expression` tool (`Edit` menu → `Select` submenu → `Select Features by Expression...`)
- here we are selecting all districts with `NYC_Pop_Borough` = `'Manhattan'`




Here are the features we just selected.




Clear the selection by pressing `Deselect Features from All Layers` button

# Measurement

## Measurement

- computation of statistics, based on the (relative) locations of features

## Examples

- distance
  ("how far is each county from the nearest Army base?")
- length
  ("how many miles of paved roads are in each county?")
- area
  ("how large is the jurisdiction for each police precinct?")
- perimeter
  ("how much coastline?")

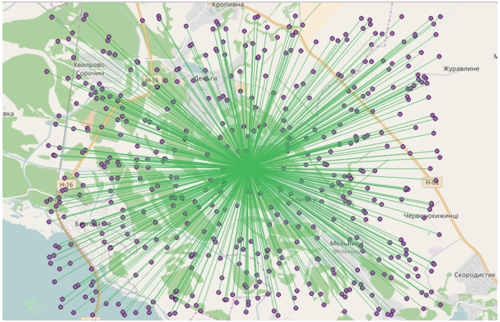



Figure 3: Distance between point $a$ and ...

## Measures of Length

1. *Euclidean distance* (2-dimensions)
   - straight-line distance between two points on Cartesian plane
   - from Pythagorean Theorem: $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

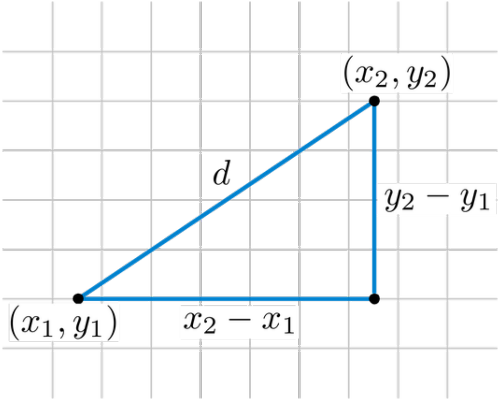



Figure 4: Oldie, but goodie

2. *Great Circle distance*
   - shortest distance between two points on a sphere
   - straight lines are replaced by curves (geodesics)
   - proportional to central angle

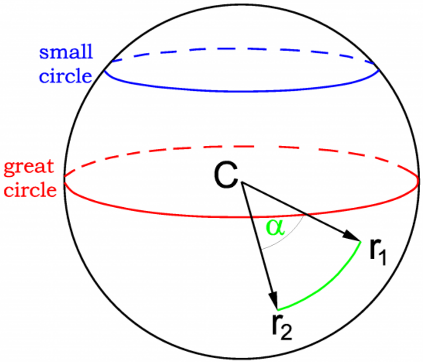



Figure 5: Circles are great

3. *Rhumb distance*
   - arc of constant bearing
   - appears as straight line on Mercator projection

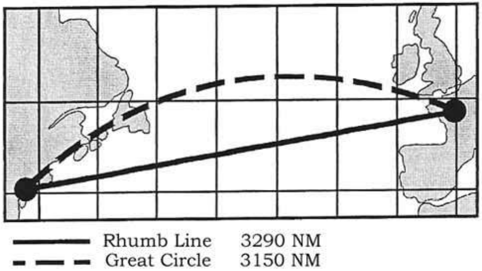
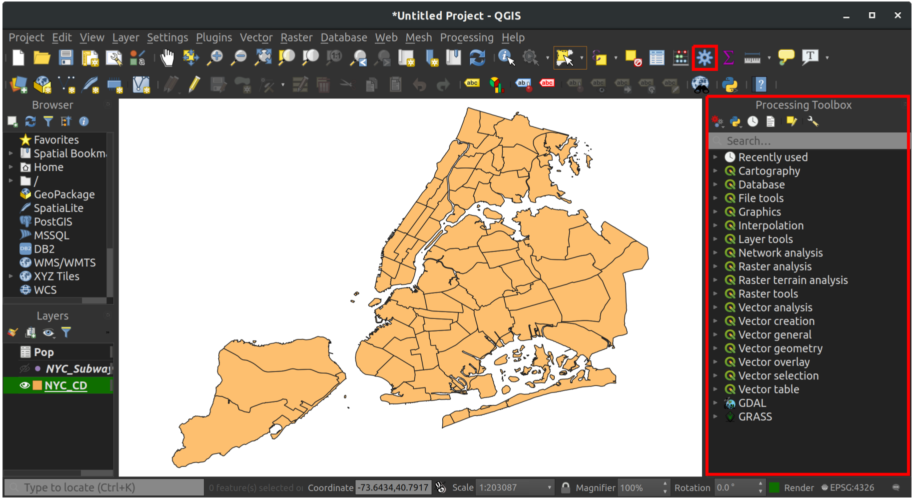
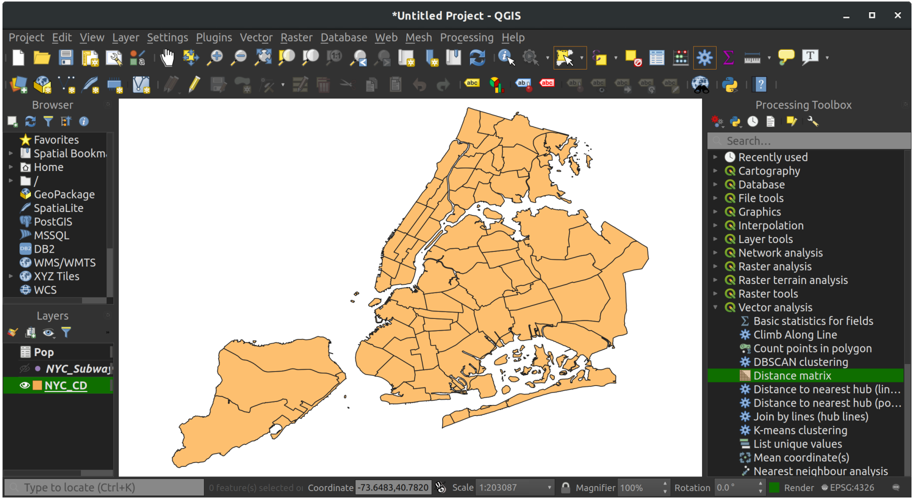


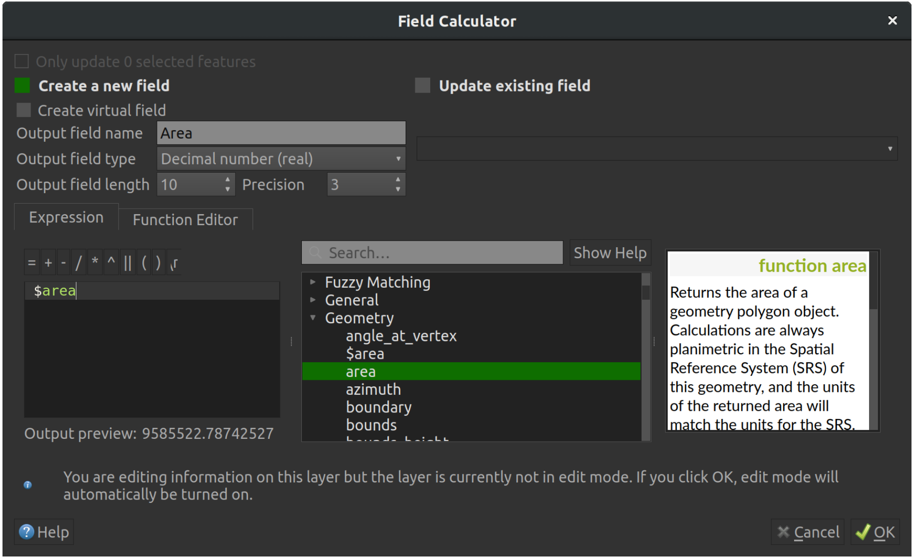

Figure 6: Shortest distance $\neq$ straight line




In QGIS, many of these capabilities are embedded in the `Processing Toolbox`




For example, here is where you find the tool to create a distance matrix.




... some basic geometry measurements are also in the `Field Calculator`

## Measures of Length

- measurements depend on map projection, distance type
- true length of curve > length of line or perimeter of polygon
- estimated length & area on 2D projection (usually) < true length and area on 3D surface

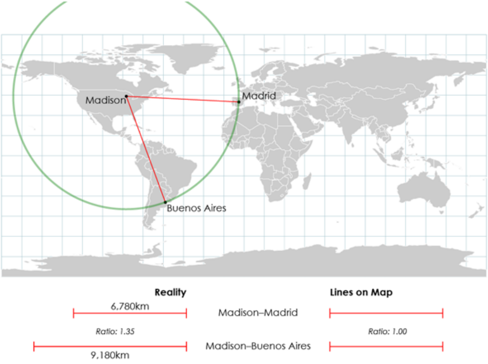



Figure 7: Why projections matter

# Geoprocessing

# Transformations

**Transformations**

- creation of new spatial objects, based on locations, shapes and attributes of existing objects

**Examples**

1. *Point-in-polygon*
   ("how many crimes in each police precinct?")
   - input: points + polygons
   - output: polygons, with new attribute (e.g. 'ncrimes')

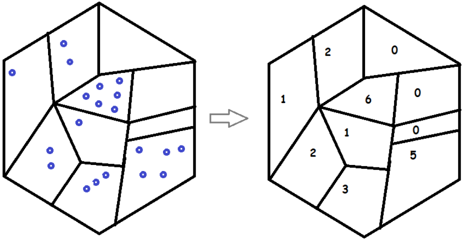



Figure 8: Point-in-polygon

2. *Line-in-polygon*
   ("how many miles of paved road in each district?")
   - input: polylines + polygons
   - output: polygons, with new attribute (e.g. 'pvdroadlength')

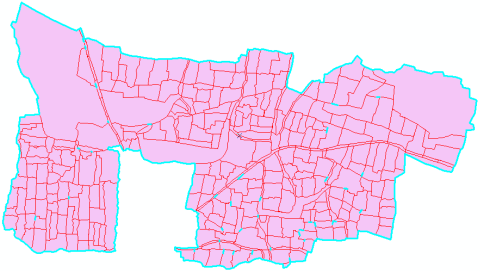


Figure 9: Line-in-polygon

3. *Buffers*
   ("which areas are within 5 miles of toxic waste site?")
   - input: points + buffer distance
     or lines + buffer distance
     or polygons + buffer distance
   - output: polygons

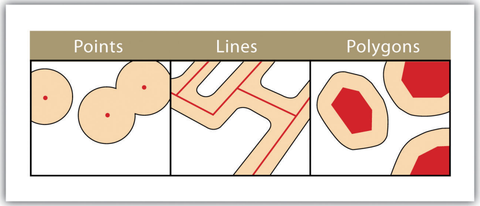



Figure 10: Buffers

3. *Kernel density*
   ("where are crime hotspots?")
   - input: points
   - output: raster, where cell values are estimated local density of points

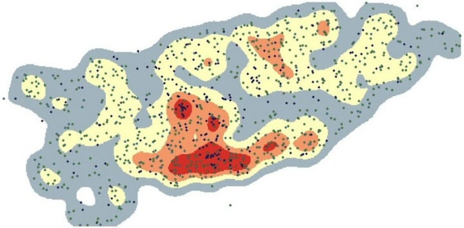


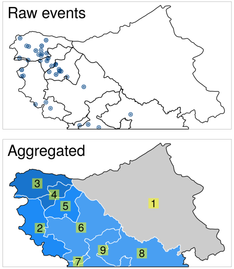
Figure 11: Kernel density

**Point-in-polygon transformation**

- whether a given point lies inside/outside of a polygon

**Examples**

1. *Generalization*
   - calculate number of points in each polygon
   - can be broken down by type of point (e.g. violent vs. non-violence crimes)
2. *Assignment*
   - assign attributes of polygon to overlapping points ("in which precinct did a particular crime occur?")




| | CLEA_CST_N | ACTION_ANY |
|---|---|---|
| 1 | Ladakh | 0 |
| 2 | Jammu | 19 |
| 3 | Baramulla | 31 |
| 4 | Srinagar | 33 |
| 5 | Anantnag | 16 |
| 6 | Udhampur | 2 |
| 7 | Gurdaspur | 3 |
| 8 | Mandi | 4 |
| 9 | Kangra | 7 |

Figure 12: Generalization example

## Joining Datasets

1. *Joining by attribute*
   - add data in tabular format (e.g. .dbf, .xls, .csv) to the attributes of a geographic layer (e.g., polygon, line, or point)
   - requires an attribute/field common to both tables ("key")

Fields to match

Target Layer

| Type | Key |
|---|---|
| Apartment | A |
| House | B |
| Commercial | C |

Join Layer

| Building_Type_ID | Building_Name | Occupants |
|---|---|---|
| A | Silverbirch Estates | 130 |
| A | Pine Ridge | 8 |
| A | Lake View | 250 |
| B | Yellow | 3 |

Join one to one - First record (default)

| Type | Key | Building_Name | Occupants |
|---|---|---|---|
| Apartment | A | Silverbirch Estates | 130 |
| House | B | Yellow | 3 |

Join one to one - Order by Occupants (Largest)

| Type | Key | Join Count | Building_Name | Occupants |
|---|---|---|---|---|
| Apartment | A | 3 | Lake View | 250 |
| House | B | 1 | Yellow | 3 |

Join one to one - Add statistics Sum of Occupants

| Type | Key | Join Count | Sum |
|---|---|---|---|
| Apartment | A | 3 | 388 |
| House | B | 1 | 3 |

Join one to many

| Type | Key | Building_Name | Occupants |
|---|---|---|---|
| Apartment | A | Silverbirch Estates | 130 |
| Apartment | A | Pine Ridge | 8 |
| Apartment | A | Lake View | 250 |
| House | B | Yellow | 3 |

Figure 13: Join-by-attribute example

2. *Joining by location*
   - add data from attributes of one geographic layer, to the attributes of another geographic layer
   - join based on relative location, rather than common values in attribute table

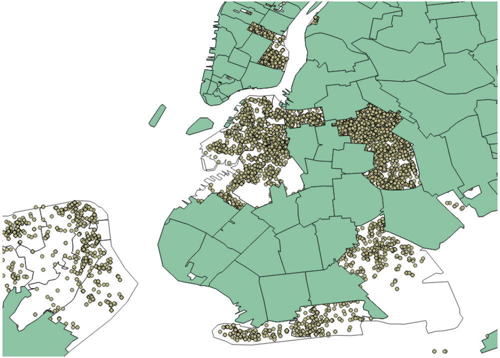


Figure 14: Join-by-location example

# Modifiable Areal Unit Problem

**Modifiable Areal Unit Problem**

- source of statistical bias
- occurs when point-based measures (e.g. events, people) are aggregated into zonal units (e.g. districts, countries)
- number, size, shape, precision of zonal units affect results
- (often) no objective criteria for selecting units
- different boundaries $\rightarrow$ different distributions

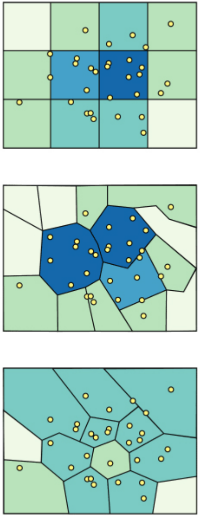


Figure 15: MAUP

**Example**

- legislative redistricting is a Modifiable Areal Unit Problem

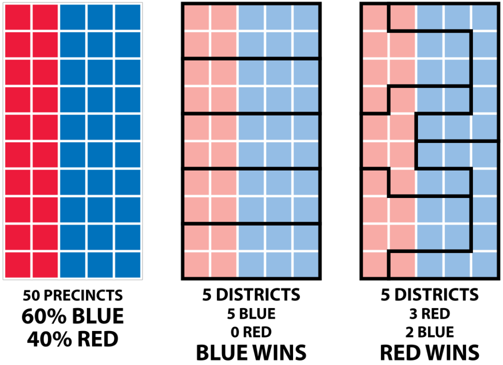



Figure 16: Which map is best?