GIS-Based Environmental Measures: Common Definitions

Dr. Ann Forsyth, Director

Thanks to Joel Koepp and Jason Zimmerman, GIS Research Fellows

Metropolitan Design Center, University of Minnesota

Session Aims

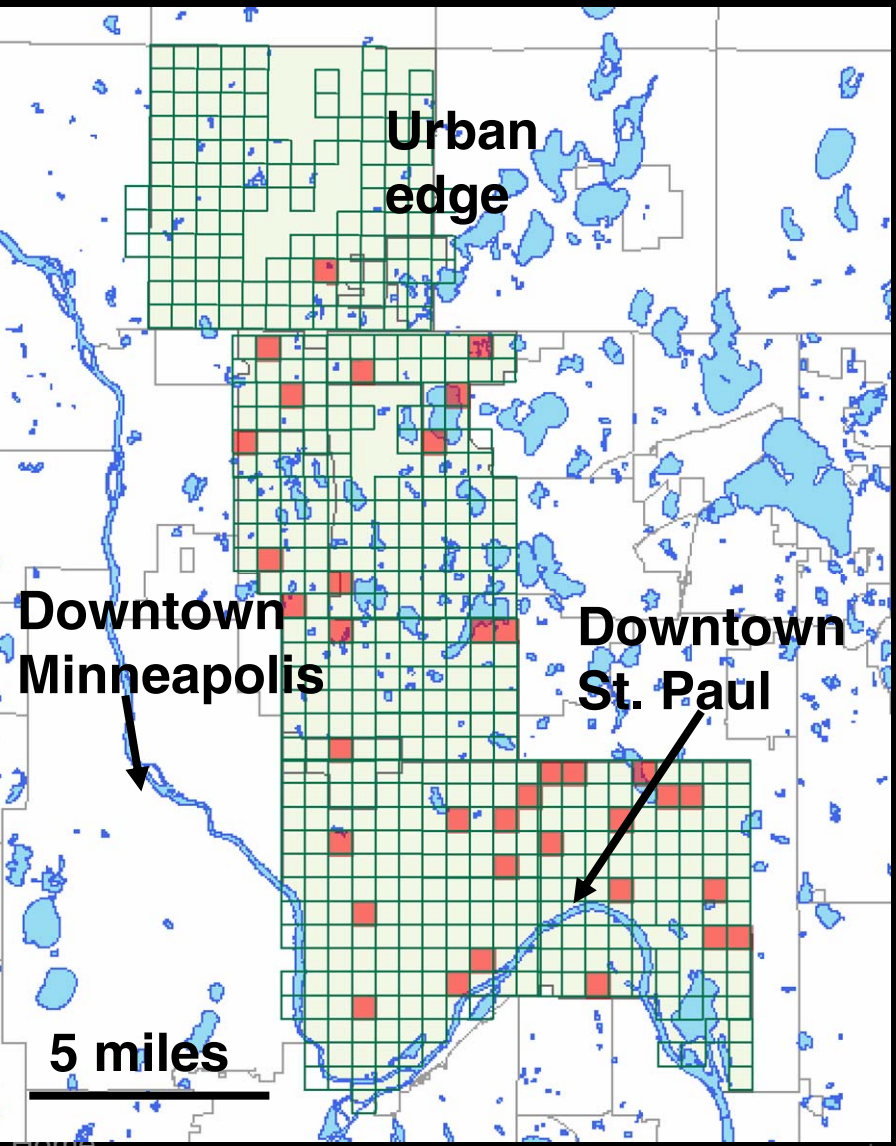
- Support collaboration, replication, meta-analysis
- Introduce one means of communication, via protocol documentation
- Audience is GIS measurement investigators

GIS-Based Measures
Overview

1. Twin Cities Walking Study
2. Measures being tested
    - Basic approach
    - Data
    - Variables and geographies
3. Protocols
    - Concept, formulae, approach, and steps
4. Examples of typical measurement problems
    - Intersections, small network buffers, counting trees

1. Twin Cities Walking Study

Where We Are Testing Measures



- Ann Forsyth, Kathryn Schmitz, Michael Oakes
- Measuring how density, street pattern, mixed use, and pedestrian infrastructure affect walking vs. social and economic factors (many variables)
- 36 0.5*0.5 mile areas in corridor from St. Paul to Blaine—selected to be varied in gross density and median block size
- Environmental measures (GIS, observations); surveys, travel diaries, measured height and weight, and accelerometer data for 718 mostly randomly selected people during 2004—work in progress

2. Measures
Variables We Are Examining

- Everything plausible and not too expensive, based on review of literature
- Do we know which ones are best? Not yet! Examining correlations between different categories of these plausible environmental variables and accelerometry, measured BMI, travel diaries, and self reported PA
- Environmental variables include:
  - Density measures
  - Street pattern/connectivity
  - Pedestrian infrastructure
  - Mixed use/destinations
- Also comparing survey vs. measured environmental features at the individual level (e.g. distance to grocery store, park)
- Results later in 2005; Protocols Version 2.0 online in March

Twin Cities Walking Study

Environment and Physical Activity: GIS Protocols

Version 2.0, March 2005

Editor: Ann Forsyth

Contributors (alphabetically):

Ann Forsyth, PhD
PI, RWJF ALR Grant, Metropolitan Design Center/College of Architecture and Landscape Architecture

Joel Koepp
GIS Research Fellow, Metropolitan Design Center

J. Michael Oakes, PhD
Co-PI RWJF ALR Grant, School of Public Health

Kathryn H. Schmitz, PhD
Co-PI RWJF ALR Grant, School of Public Health

Jason Zimmerman
GIS Research Fellow, Metropolitan Design Center

Twin Cities Walking Study, Metropolitan Design Center
1 Rapson Hall, 89 Church Street SE, Minneapolis, MN 55455-0109, USA
http://www.designcenter.umn.edu,Forsyth@umn.edu.

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This is a work in progress

To be placed on the Active Living Research web site

Link from Design Center web site at www.designcenter.umn.edu

2. Measures
Variables and Data

Measures
- Fundamental measures/geographies
- Density
- Pedestrian Infrastructure
- Mixed use
- Street pattern

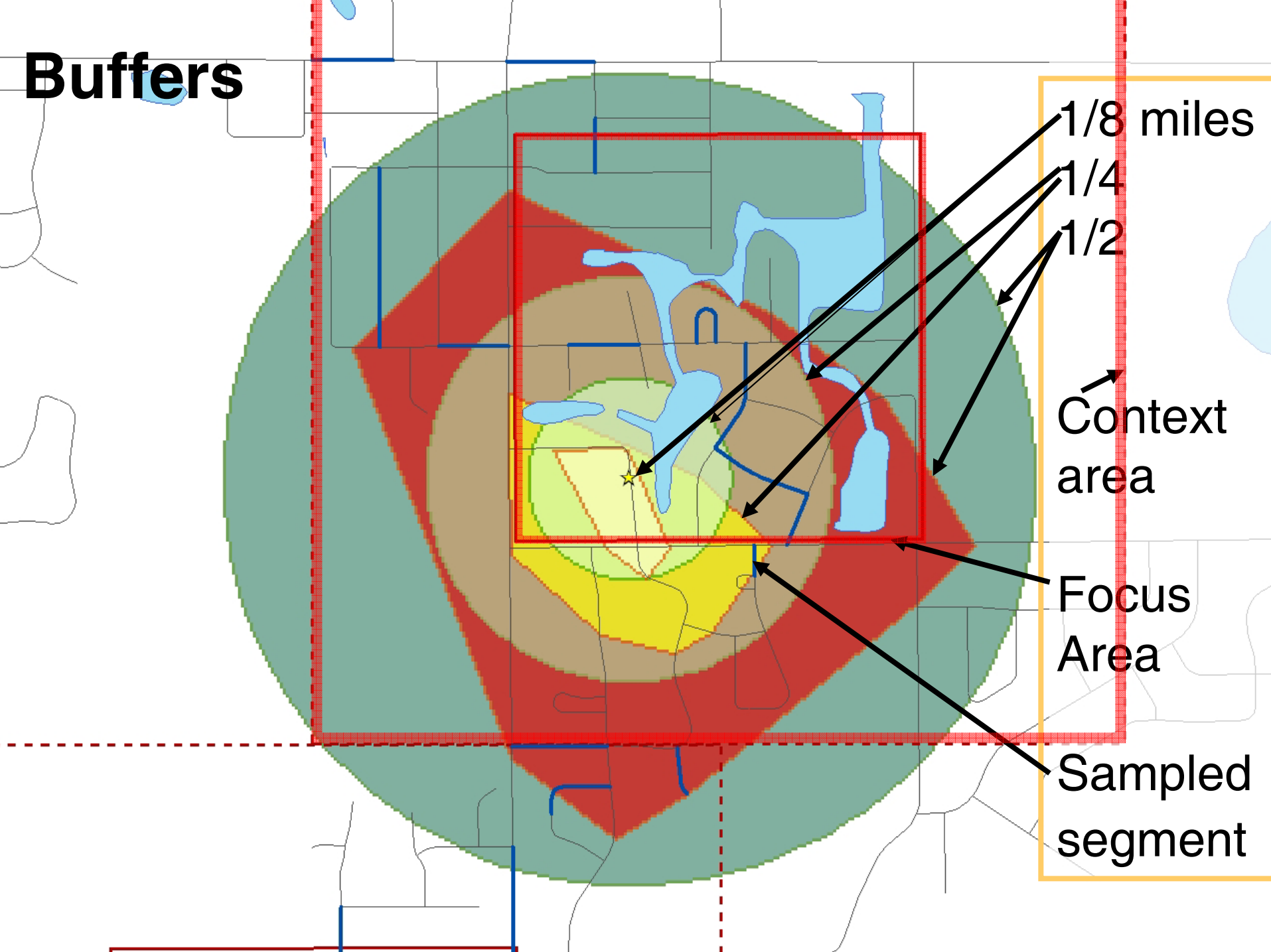
Data
- U.S. Census; employment
- Local: MetroGIS, county, cities, I-35W Coalition, Excensus/employment
- Digitized from orthophotos: street trees, street lamps, and sidewalks
- Urban design inventory

2. Measures

Fundamental Measures

2.1 Net Land Area (without water)
2.2 Gross Area (including water)
2.3 Creating a Focus Area Sampling Grid and Sampling Extreme Areas
2.4-2.9 Measurement Geographies
- 1: Grid Cell
- 2: Straight Line or Airline Buffer
- 3: Network or Street Distance Buffer
- 4: Straight Line or Airline Distance to Nearest Feature
- 5: Network or Street Distance to Nearest Feature
- 6: Parcel of Residence

Buffers



2. Measures
Density

Why it matters: critical mass; physical sense of community; transit viability; auto congestion; proxy variable

Measures
3.1/3.2 Population per Unit Land Area: raw; without water
3.3 Population per Developed Land Area
3.4 Residential Population in Residential Parcels (Residential Density)
3.5 Population plus Employment per Unit Land Area
3.6 Employment per Unit Land Area
3.7 Housing Units per Unit Land Area (gross, census data)
3.8 Lot Coverage

2. Measures

Pedestrian Infrastructure

Why it matters: Comfort, safety, interest

Sidewalks, street lights, street trees

4.2-4.4 Sidewalk Length: Divided by Road Length; per Unit Area; per Length of Major Road

4.5 Street Lights: per Length of Road

4.6 Street Trees within an X meter buffer per Length of Road + other measures

Inventory

4.7-4.9 Percent of Street Segments with: Marked Pedestrian Crossings at One or Both Ends; Visible Litter, Graffiti, or Dumpsters; Traffic Calming, Broadly Defined

4.10+ Other fieldwork based measurements of neighborhood identification from crosswalks to architecture. 160+ question inventory


Street lights

Street tree zone up to 90 m wide– individual trees digitized.

Where continuous cover, this was photographed and allocated to 3 categories of minimum densities (field based)

2. Measures

Mix

Why it matters: Movement between destinations; safety/activity from day/night use

5.1 Percentage of Total Parcel Area in Major Land Uses (seven land uses in this case)

5.2-5.5 Percentage of Land Area in Night Time Uses; Social Uses; Retail Uses; Industrial and Auto-Oriented Uses

5.6-5.7 Proportion of Dissimilar Land Uses Among Grid Cells

5.8 Retail Employment per Unit Area

5.9 Density of Employees in Major Retail Subcategories (Separate Measures): General Merchandise; Food Stores; Eating and Drinking Places; Miscellaneous Retail.

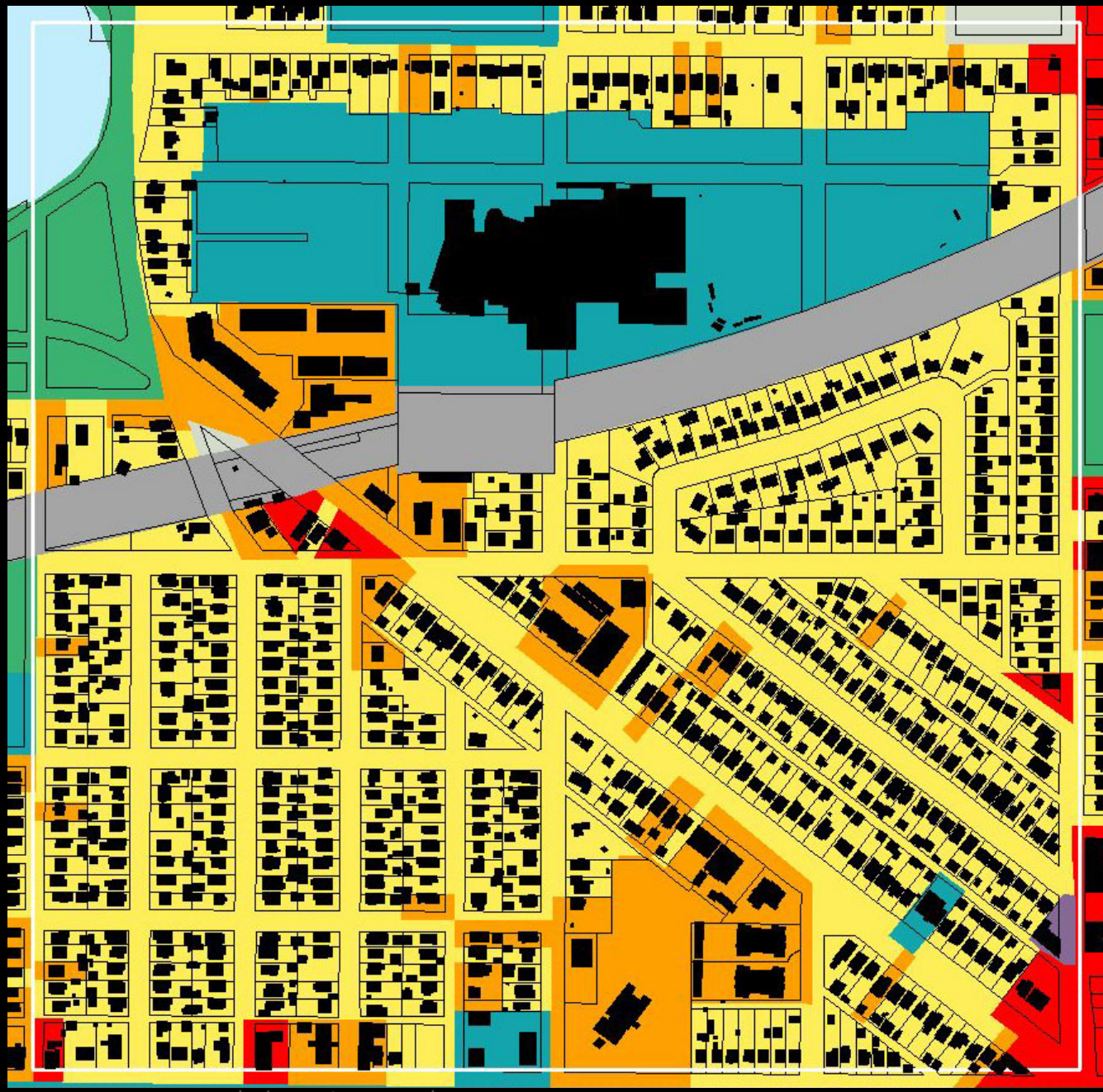
5.10 Distance to Nearest Facility (same facilities as 5.9)

5.11 Distance to Nearest Facility For Comparison with NEWS Survey

+ UNC measures e.g. Gini coefficient, Atkinson index, and Entropy index.

Mix

- Streets, parcels, building footprints, assessors data (use e.g. commercial—bowling alley, building age, value, owner, etc)
- Consistent at municipal and sometimes regional level



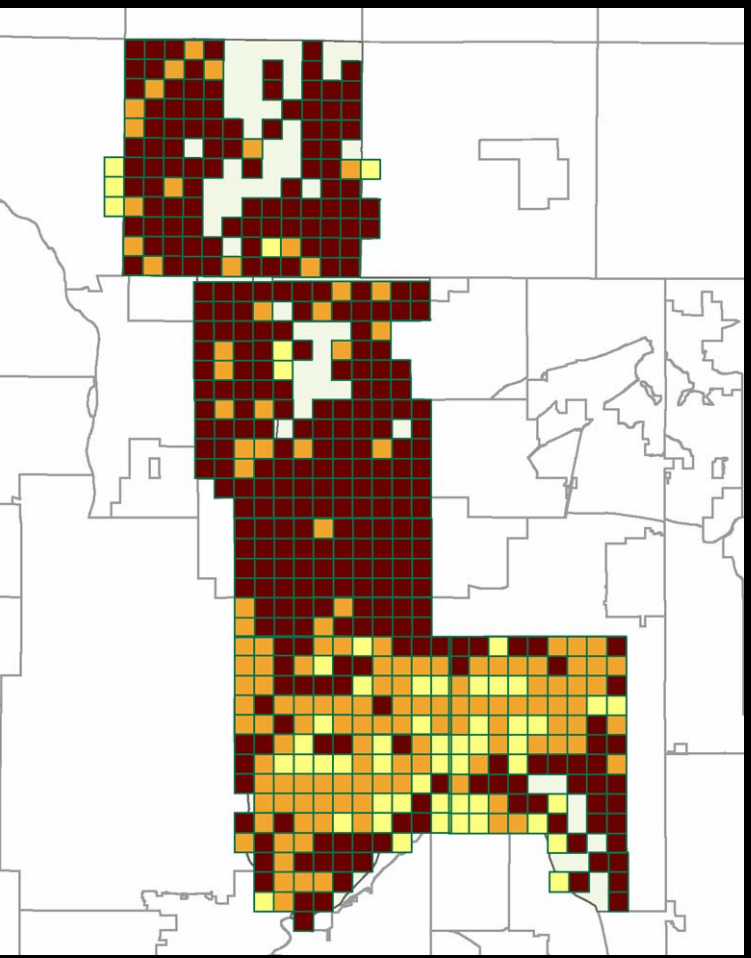
2. Measures
Street Pattern

Why it matters: Directness; alternate routes

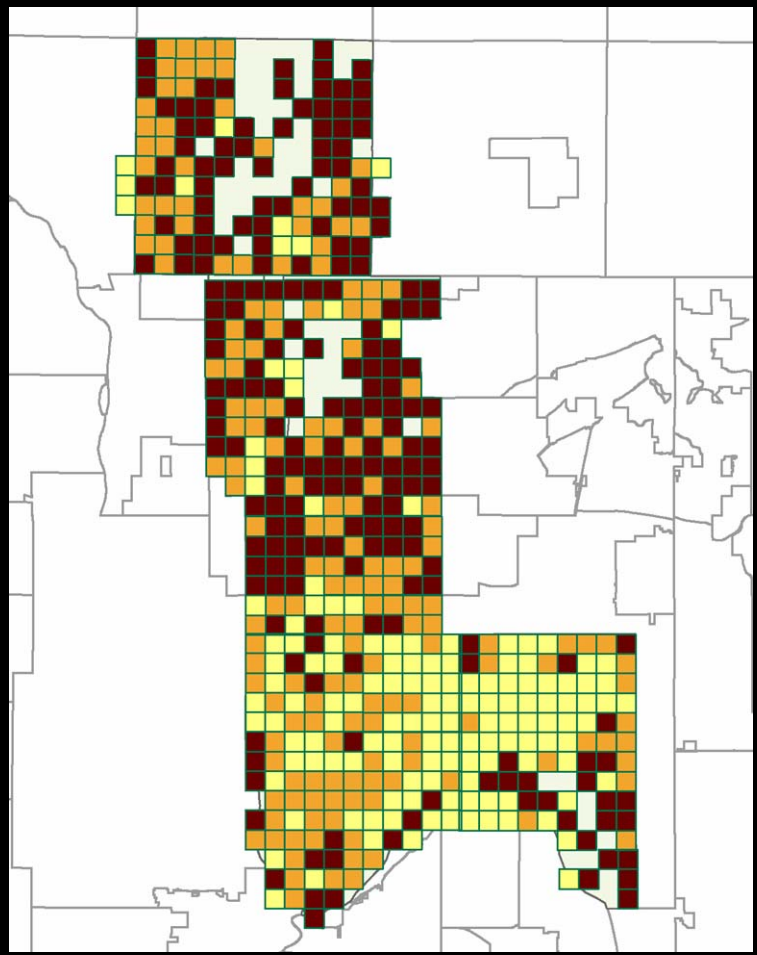
6.1/6.2 Average/Median Census Block Area
6.3 Ratio of Area within X Street Distance to Area within X Distance Radius
6.4 Number of Access Points
6.5 Road Length per Unit Area
6.6 Intersections per Unit Area
6.7/6.8 Ratio of 4-Way Intersections to All Intersections; per unit area
6.9 Ratio of 3-way Intersections to All Intersections
6.10 Connected Node Ratio
6.11 Link Node Ratio
6.12 Median Perimeter of Block

2. Measures

Average vs. Median Block Size



Average



Median

Maroon: 8+ ac, 3.2+ha
Orange: 2-3.2 ha
Yellow: 0 – 5 ac, 0-2 ha


Big block

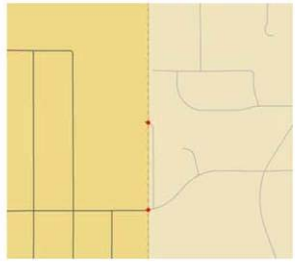
3. Protocols
Structure

1. Basic Concept
2. Basic Formula, or Basic Definition, Basic Procedure

   Population per Unit Land Area (without water) = Persons in housing units per unit gross area excluding water.
3. Detailed Formula or Detailed Definition

   Population per Unit Land Area (without water) = Persons in housing units as measured in the US Census at the block level per unit land area excluding area of water features as measured in the Ramsey County layer or the Metropolitan Council water layer for areas outside Ramsey.
4. Comments and Explanations
5. GIS Approach
6. GIS Steps

3. Protocols
What a Protocol Looks Like



Many access points are somewhat marginal in their quality. That is, these points may exist but not provide significant access to the site, or may fall just inside the site boundary and therefore not be counted (see examples below).The red [dark] point in the middle of the image is technically an access point because the road centerline just crosses the site boundary, even though it provides no significant access to the site. However, it is extremely complex to develop rules to exclude such points—see next image for more examples.

The three purple [dark] circles identify points that should be included in the analysis, since they provide significant access to the site, but are not because the road centerlines lie just inside the site boundary and do not intersect it.

We experimented with methods of buffering these points and derived various rules for exclusion or inclusion, but in the end determined that this opened the door to many subjective decisions. It seemed that the number of access points included that probably should be excluded would roughly offset the number of access points excluded that probably should be included and therefore we decided to set aside the issue of marginal access points in our analysis.

5. GIS Approach
A point file was created that contained all points were road centerlines intersected site boundaries. From this set, Interstate points were deselected. For any divided roads (those with two distinct centerlines, such as parkways), one half of the access points were deselected. The total number of access points for each study site were summed.

6. GIS Steps
The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

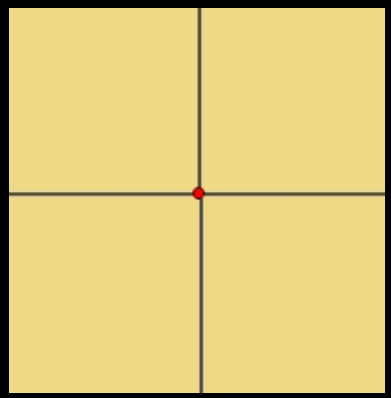
1. Site layer (polygon)
2. Site boundary layer (polyline)
   If you only have a polygon site layer, convert the polygons to polylines using the XTools extension (available from the Downloads section of the ESRI website).
3. Road centerline layer (polyline)
4. AddPointsAtCrossings ArcScript available from the Downloads section of the ESRI website

The basic steps are:

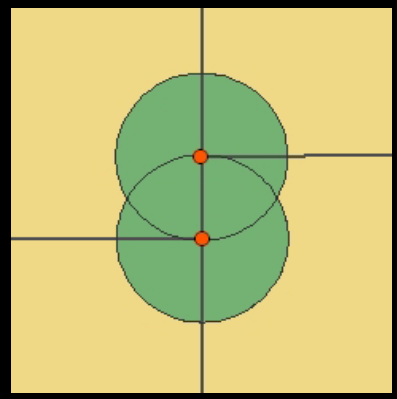
- *Create the Access Point file*
- *Correct for Interstate Access Points*
- *Correct for Parkway Access Points*
- *Remove Unwanted Access Points from View/Table*

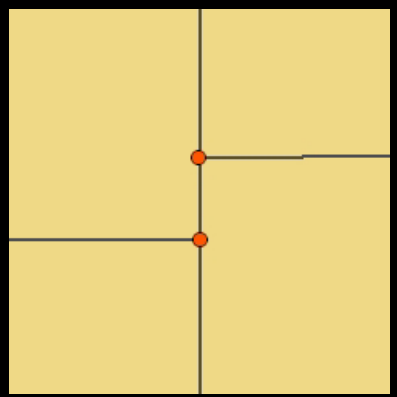
4. Typical Problems

A. What is an Intersection?



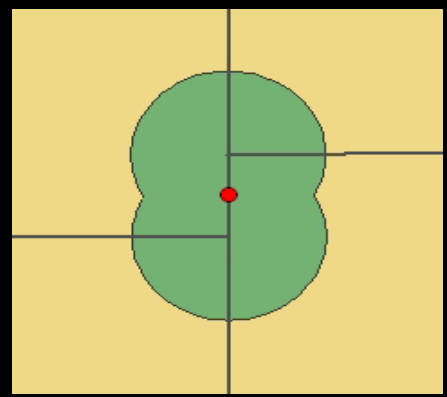
4-Way or X intersections indicate higher connectivity than 3-way or T intersections





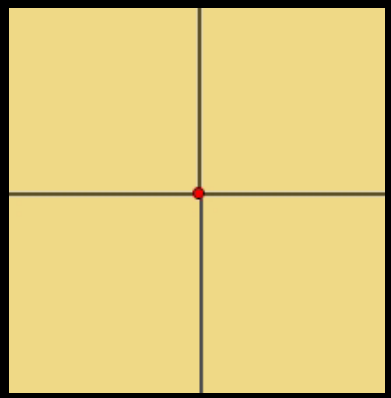
Issue simple 4-way intersections vs. functional 4-way

Solution, is buffering: 10m (20m offset); 15m

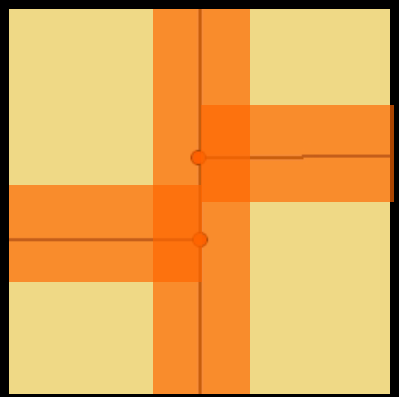


4. Typical Problems

A. What is an Intersection?



A

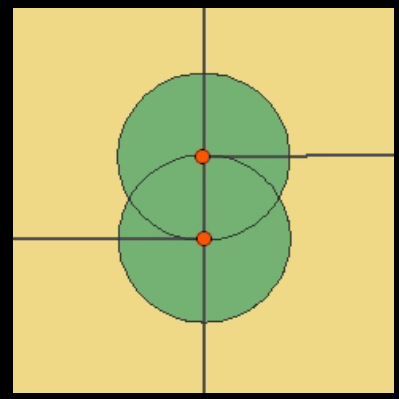


B

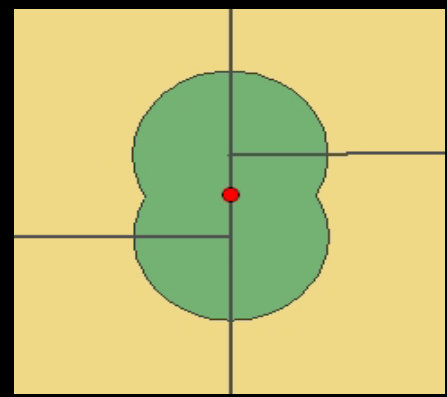
4-Way or X intersections indicate higher connectivity than 3-way or T intersections

Issue simple 4-way intersections vs. functional 4-way

Solution, is buffering: 10m (20m offset); 15m



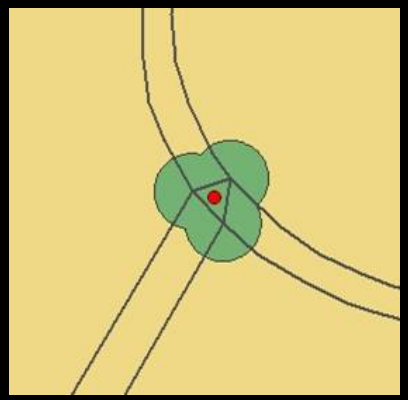
C



D

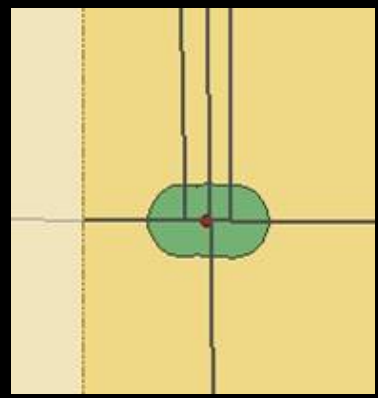
4. Typical Problems

A. What is an Intersection?

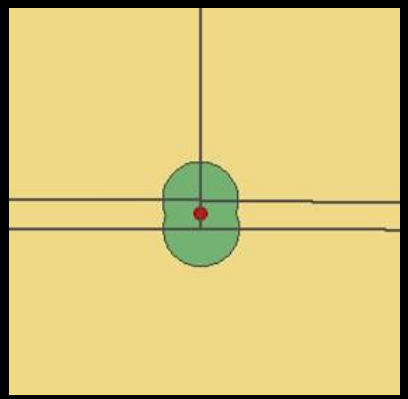


Valence 12

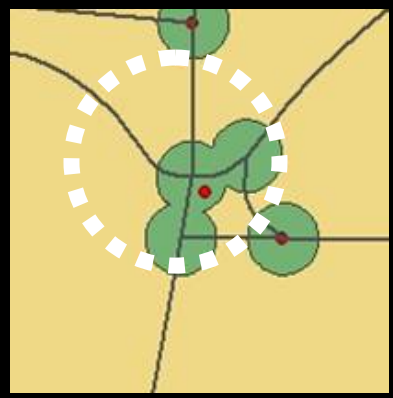
Complex intersections—high valences but not all function with high connectivity (valence 7 and 12 are often 3 way)



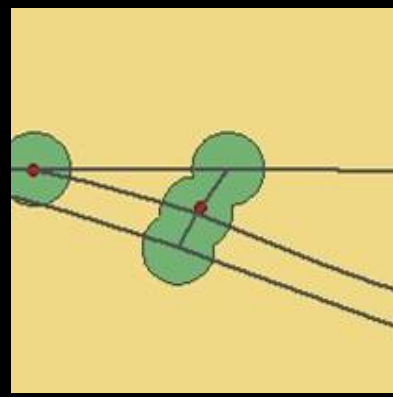
Valence 10



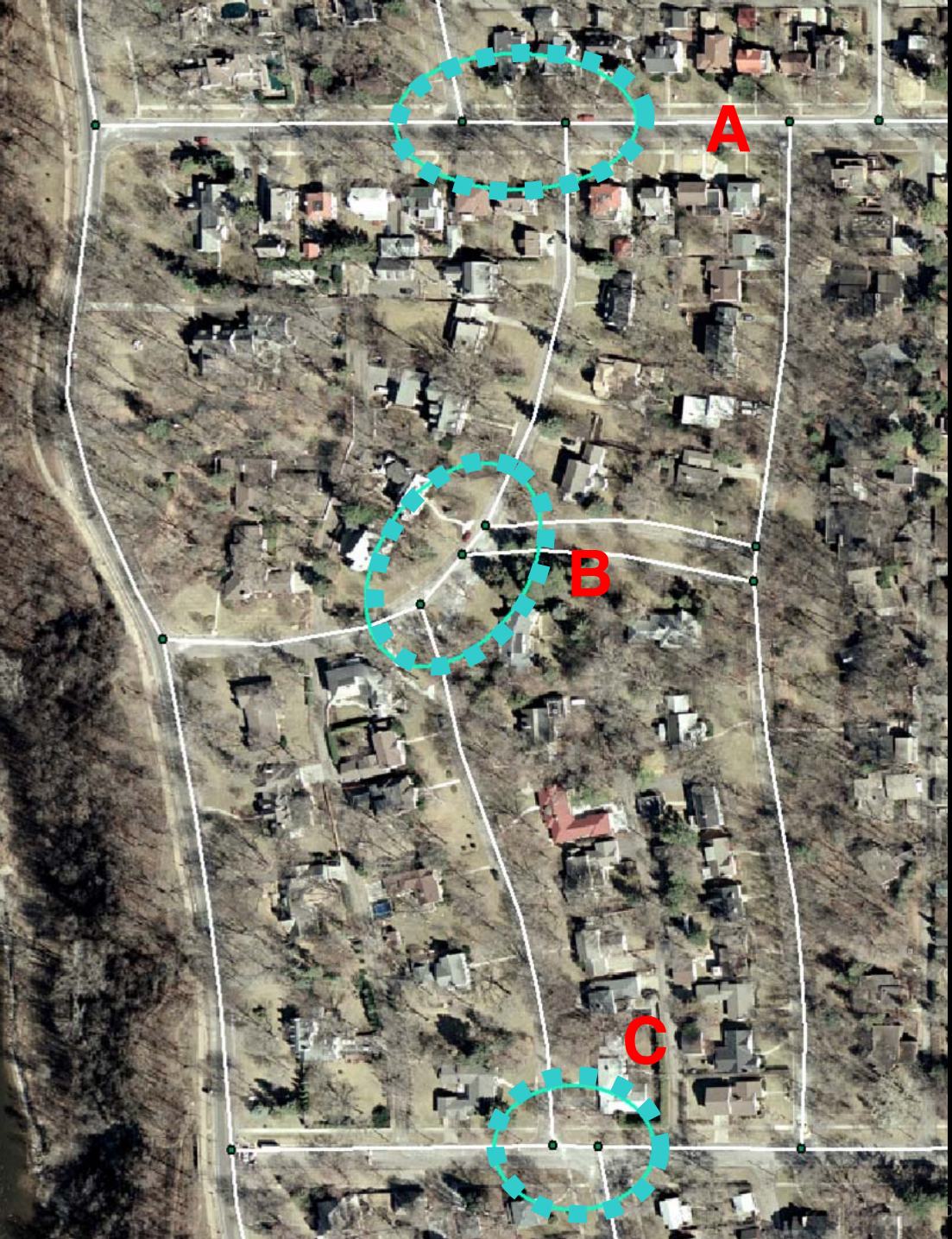
Valence 7



Valence 10



Valence 10

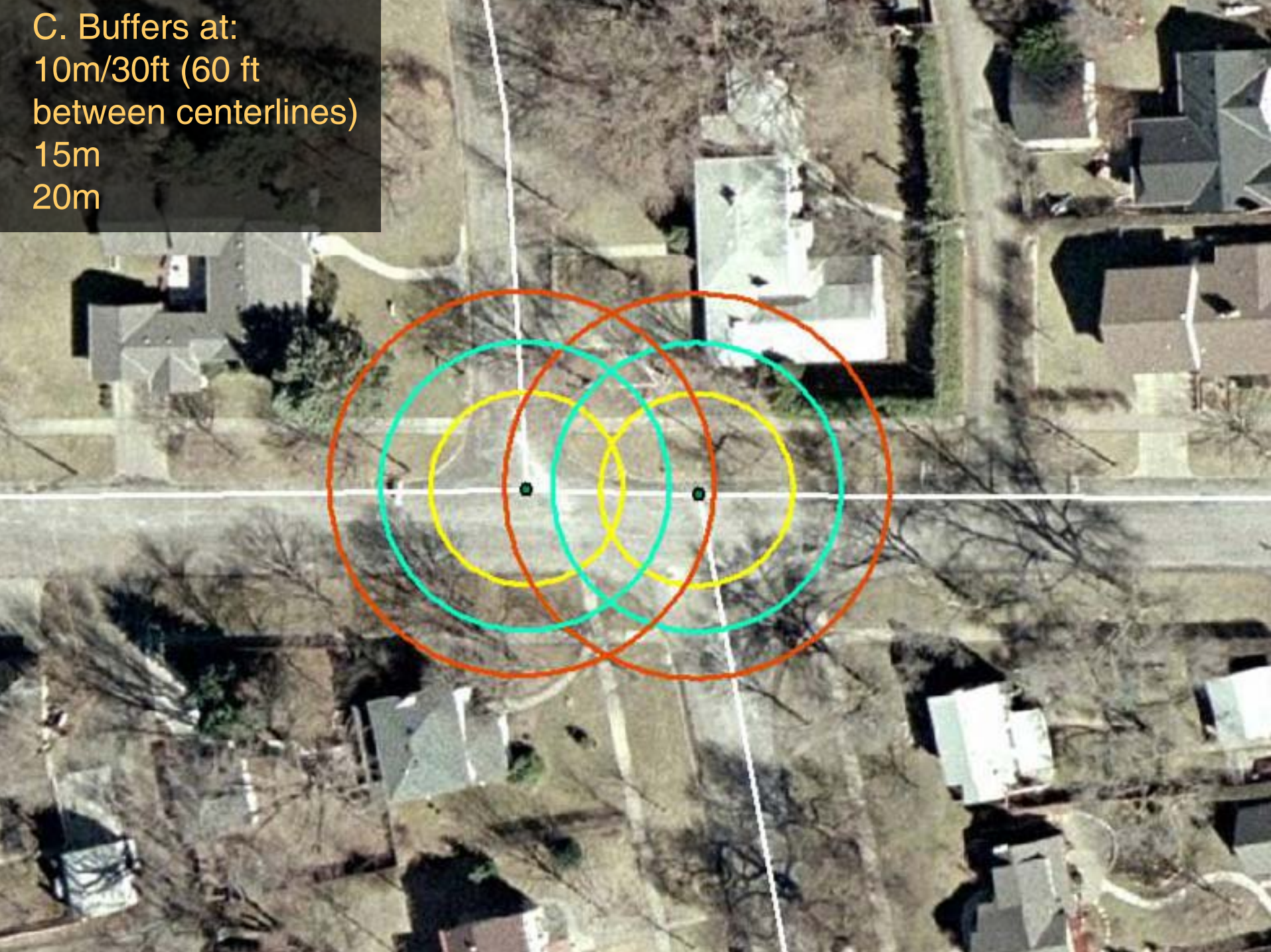


Are the T-intersections in this neighborhood distinct or experienced as functional 4-way intersections?

A. 130ft/40m apart
B. 100ft/30m apart
C. 65ft/20m apart

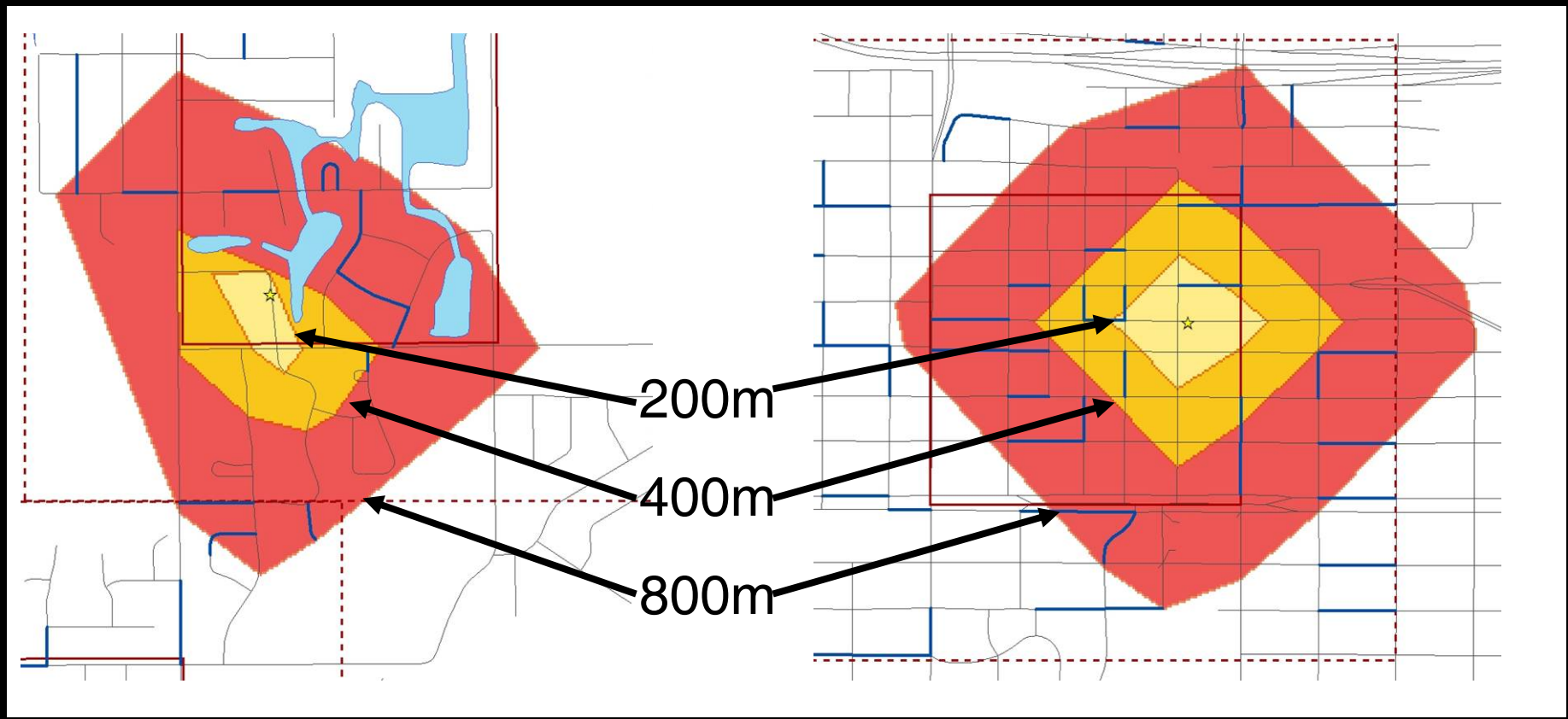

A. Buffers at:
10m/30ft (60 ft between centerlines)
15m
20m

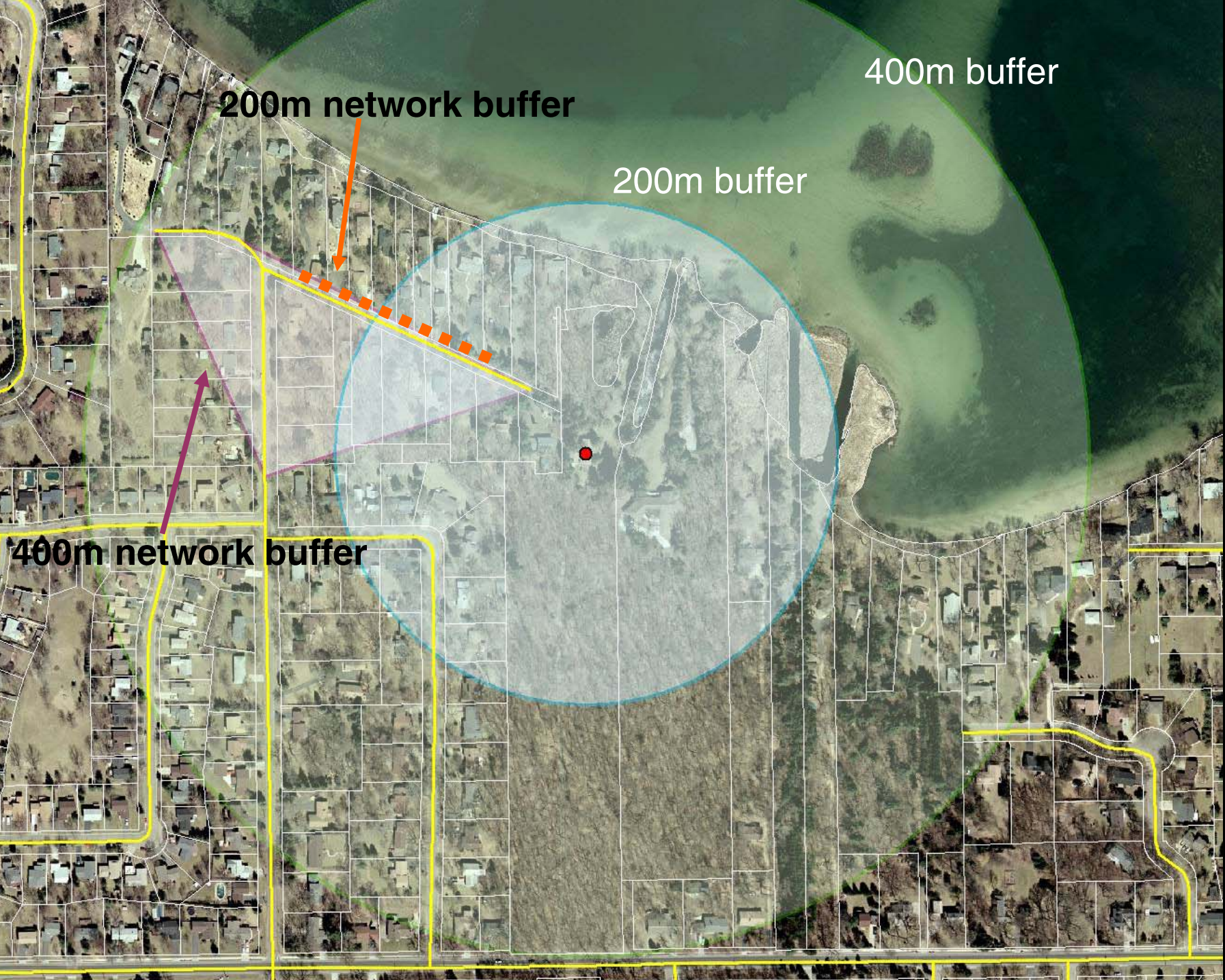

B. Buffers at:
10m/30ft (60 ft between centerlines)
15m
20m


C. Buffers at:
10m/30ft (60 ft between centerlines)
15m
20m

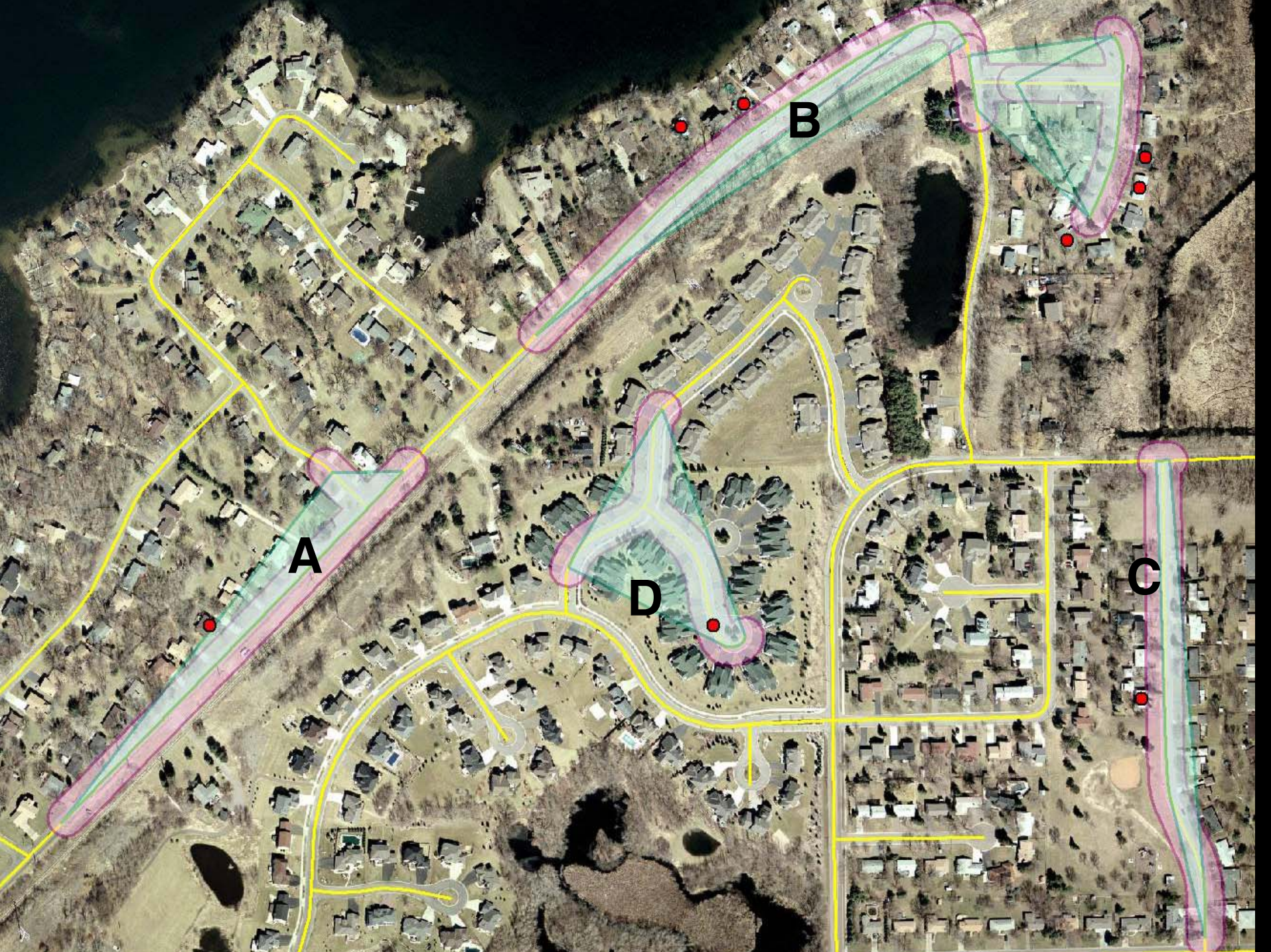
4. Typical Problems

B. Making Network Buffers




400m buffer
200m network buffer
200m buffer
400m network buffer

15m buffer/30m width for network buffers under minimum 12,000+m2 (30m*200m*2)—still refining

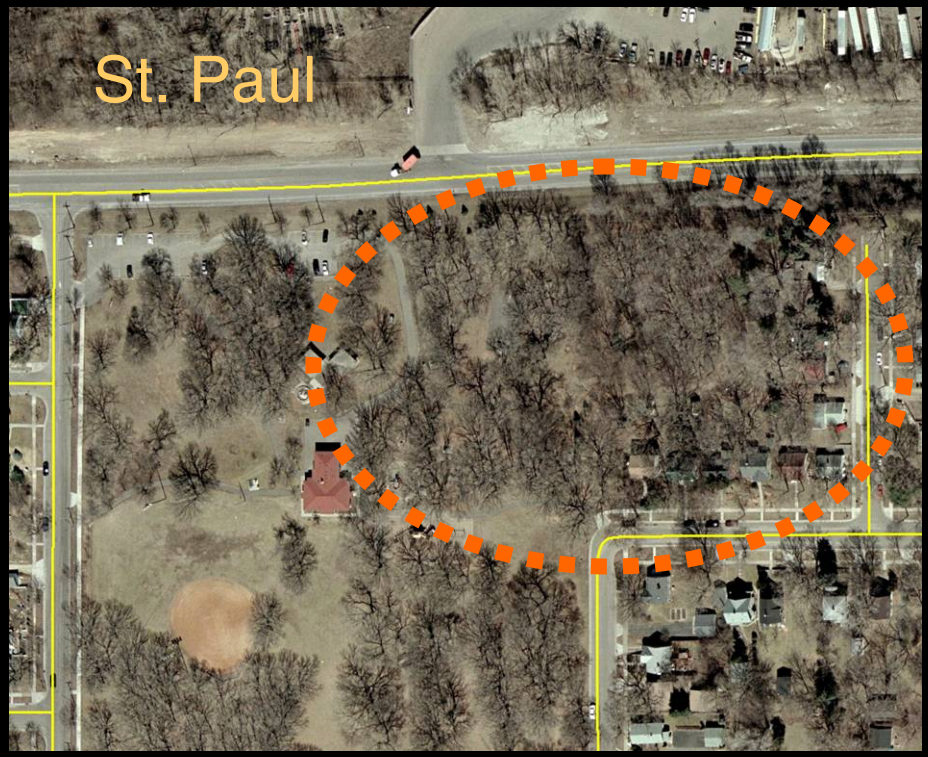

A
B
C
D

4. Typical Problems
C. How Many Trees in a Forest?

- Continuous canopy
- Perception of tree density--after a certain level there are just a lot of trees so it probably makes no difference in perception but saying there are 2700/ha vs. 500 or 150 would skew tree densities
- Need more research on perception but in interim…

4. Typical Problems

C. How Many Trees in a Forest?



Trees are too dense to count from the photo

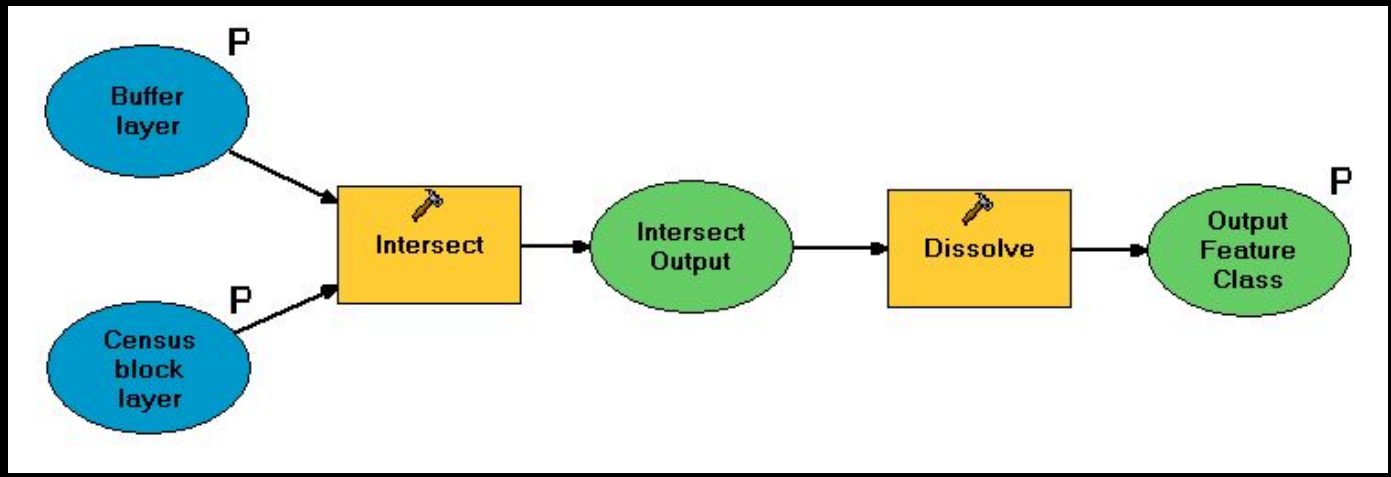
4. Typical Problems

C. How Many Trees in a Forest?

St. Paul, approx 60/acre
150/ha

St. Paul, approx 1100/acre
2700/ha above about 4 inch diameter

5. Final Tips



- Read the GIS documentation—you'll get new ideas
- Try things out yourself—you'll at least get to look at the data in detail
- Look at the ESRI discussion forums—that's how the GIS technical folks figure out how to do things
- Communicate in writing

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Credits

Metropolitan Design Center

1 Rapson Hall

89 Church Street

Minneapolis, MN 55455

612.625.9000

www.designcenter.umn.edu

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