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Core Curriculum-Geographic Information Systems (1990)

Title

Unit 14 - Vector GIS Capabilities

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Compiled with assistance from Holly J. Dickinson, State University of New York at Buffalo

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For Information that Supplements the Contents of this Unit:

[Links to the following resources have been omitted.]

- Buffers: Distance Transformations (Chrisman/U of Washington) -- Graphics and information about: construction of buffers; generalized Voronoi diagram; Voronoi zones around points.
- Transformations Examples (Chrisman/U of Washington) -- Dasymetric mapping of population density; wastelands vs. wetlands; review of operations and transformations; after point in polygon; after point in polygon overlay; etc.
- Transformations Between Measurement Frameworks (Chrisman/U of Washington) -- Surface transformations; taxonomy of transformations.

This unit would be illustrated well with a series of overlays of a real area which demonstrates the problems discussed here using simple examples.

UNIT 14 - VECTOR GIS CAPABILITIES

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A. INTRODUCTION

- analysis functions with vector GIS are not quite the same as with raster GIS
    - more operations deal with objects
    - measures such as area have to be calculated from coordinates of objects, instead of counting cells

- some operations are more accurate
    - estimates of area based on polygons more accurate than counts of pixels
    - estimates of perimeter of polygon more accurate than counting pixel boundaries on the edge of a zone

- some operations are slower
    - e.g. overlaying layers, finding buffers

- some operations are faster
    - e.g. finding path through road network

B. SIMPLE DISPLAY AND QUERY

Display

- using points and "arcs" can display the locations of all objects stored

- attributes and entity types can be displayed by varying colors, line patterns and point symbols

- may only want to display a subset of the data
    - e.g. want to display areas of urban landuse with some base map data
        - select all political boundaries and highways, but only areas that had urban land uses

- how would the user do this?
    - e.g. one of the layers in a database is a "map" of land use, called USE
    - area objects on this layer have several attributes
    - one attribute, called CLASS, identifies the area's land use
    - for urban land use, it has the value "U"
    - need to extract boundaries for all areas that have CLASS="U"

Standard Query Language (SQL)

- different systems use different ways of formulating queries

- Standard Query Language (SQL) is used by many systems

- SQL phrase structure:

  SELECT &LTattribute name(s)> FROM &LTtable> WHERE &LTcondition statement>

  - e.g. SELECT FROM USE WHERE CLASS="U"
  - this selects only the objects for display - no attributes are retrieved by the query

- SQL examples using a list of student names:
  - SELECT name FROM list (selects all names)
  - SELECT name FROM list WHERE grade = "A" (selects names of students receiving an "A")
  - SELECT name FROM list WHERE cumgrade > 3.0 (selects names of students with a cumulative gpa greater than 3.0)

- SQL operators:
  - relational: >, &LT, =, >=, &LT=
  - arithmetic: =, -, *, / (only on numeric fields)
  - Boolean: and, or, not

Boolean operators

- used to combine conditions
  - e.g. WHERE cumgrade > 3.0 AND grade = "A" (selects students satisfying both conditions only)

- Boolean operators can have a spatial meaning in GIS as well
  - e.g. when two maps are overlayed, areas (polygons) that are superimposed have the "and" condition

- a spatial representation is used to illustrate Boolean operators in the study of logic, through the use of diagrams called Venn diagrams
  - thus GIS area overlay is a geographical instance of a Venn diagram

  - "XOR" is the "exclusive or" - A xor B means A or B but not both

SQL extensions for spatial queries

- some systems allow specifically spatial queries to be handled under SQL e.g. WITHIN operator
  - SELECT &LTobjects> WITHIN &LTspecific area>

- the criteria for these spatial searches may include searching within the radius of a point, within a bounding rectangle, or within an irregular polygon

C. RECLASSIFY, DISSOLVE AND MERGE

- reclassify, dissolve and merge operations are used frequently in working with area objects
    - these are used to aggregate areas based on attributes

- consider a soils map:
    - we wish to produce a map of major soil types from a layer that has polygons based on much more finely defined classification scheme

Steps

1. reclassify areas by a single attribute or some combination

    - e.g. reclassify soil areas by soil type only

2. dissolve boundaries between areas of same type
    - by delete the arc between two polygons if the relevant attributes are the same in both polygons

3. merge polygons into large objects
    - recode the sequence of line segments that connect to form the boundary (i.e. rebuild topology)
    - assign new ID #'s to each new object

Forestry example

- consider a forestry GIS where the forest is divided into "stands", average size 10 ha:
    - each stand carries a list of attributes, including tree species and average tree age
    - attributes apply homogeneously to area of each stand
    - boundary occurs between stands whenever at least one attribute changes

- problem: identify all cuttable areas of white spruce
    - assign new attribute "cuttable" to each stand
        - value = "y" if white spruce AND age > 50 years
        - value = "n" otherwise
    - after assigning new attribute, all others can be dropped

- now wish to identify cuttable areas, each may be merger of several individual stands
    - dissolve boundaries between polygons with same value of "cuttable" attribute
    - merge polygons into larger objects

City zoning example

- need to know how many individual landuse zones have been created in the city and how these are distributed geographically

- each land parcel in the city has a zoning attribute attached to it

> dissolve boundaries between parcels if the zoning is the same

- result can be a map showing large areas of similar zoning classes

D. TOPOLOGICAL OVERLAY

- suppose individual layers have planar enforcement (required in many systems, not all)

- when two layers are combined ("overlayed", "superimposed") the result must have planar enforcement as well
  - new intersection must be calculated and created wherever two lines cross
  - a line across an area object creates two new area objects

- topological overlay is the general name for overlay followed by planar enforcement

- relationships are updated for the new, combined map

- result may be information about relationships (new attributes) for the old (input) maps rather than the creation of new objects
  - e.g. overlay map of school districts on census tracts
    - result is map showing every school district/census tract combination
    - for each combination, the database contains an area object
    - however, concern may be with obtaining the number of overlapping census tracts as a new attribute of each school district rather than with new objects themselves

Point in polygon

- overlay point objects on areas, compute "is contained in" relationship

- result is a new attribute for each point
  - e.g. combine wells and planning districts, find district containing each well

Line on polygon

- overlay line objects on area objects, compute "is contained in" relationship

- lines are broken at each area object boundary
  - number of output lines is greater than number of input lines

- containing area is new attribute of each output line

- e.g. combine streams and counties, find county containing each stream segment

Polygon on polygon ("Polygon overlay")

- overlay two layers of area objects

- boundaries are broken at each intersection

- number of output areas likely greater than the total number of input areas

- e.g. input watershed boundaries, county boundaries, output map of watershed/county combinations

- after overlay we can recreate either of the input layers by dissolving and merging based on the attributes contributed by the input layer

Example

- wish to use find those areas that are the best land for timber harvesting

- after overlay, each original layer contributes attributes to the combined layer

- we get the final map by selecting the desired attributes of the combined layer
    - SELECT FROM OVERLAY WHERE Species = "Jack pine" AND Soil = "C"

Spurious polygons

- during polygon overlay, many new and smaller polygons are created, some of which may not represent true spatial variations

- the small, invalid polygons are called spurious or sliver polygons and can be a major problem in polygon overlay

- spurious polygons arise when two lines are overlaid which are actually slightly different versions of the same line

    - if the same line occurs on two input maps, the digitized versions may be slightly different
    - in many cases the lines on the source maps have been compiled from different sources, but are nevertheless the same line on the ground
    - e.g. a road may be part of a county boundary, also the boundary between two fields or two soil types or two vegetation types

- the problem cannot be removed by more careful digitizing - more points simply leads to more slivers

- some GISs allow the user to set a tolerance value for deleting spurious polygons during overlay operations

    - if the tolerance is set too high, some legitimate polygons may be deleted
    - if set too low, some erroneous polygons will remain
    - deletion rules might also be based on shape, as spurious polygons tend to be long and thin

E. BUFFERING

- a buffer can be constructed around a point, line or area

buffering creates a new area, enclosing the buffered object

- applications in transportation, forestry, resource management
  - protected zone around lakes and streams
  - zone of noise pollution around highways
  - service zone around bus route (e.g. 300 m walking distance)
  - groundwater pollution zone around waste site

- options available for raster, such as a "friction" layer, do not exist for vector

- buffering is much more difficult in vector from the point of view of the programmer

- sometimes, width of the buffer can be determined by an attribute of the object
  - e.g. buffering residential buildings away from a street network:
    - three types of street (1, 2, 3 or major, secondary, tertiary) with the setbacks being 600 feet from a major street, 200 feet from a secondary street, and only 100 feet from a tertiary street

- problems with buffer operations may occur when buffering very convoluted lines or areas

REFERENCES

Documentation for ARC/INFO (user manuals, Understanding GIS) provides an overview of vector GIS functionality for a commonly available system.

Burrough, P.A., 1986. Principles of Geographical Information Systems for Land Resources Assessment, Clarendon, Oxford. Chapter 5 on data analysis.

Lusardi, Frank, 1988. The Database Expert's Guide to SQL, McGraw-Hill Book Co., New York. Good introduction to Standard Query Language.

EXAM AND DISCUSSION QUESTIONS

1. Compare the buffer function in raster and vector systems, in terms of results, options offered by systems, and flexibility.

2. The skeleton function moves the boundary of an area object inwards rather than outwards. Show how this would work using a simple diagram, and what happens as the amount of movement increases. What objects might be created by this operation, and what uses can you devise for them?

3. What are spurious polygons and what characteristics of data cause them?

4. Section D listed three types of topological overlay between points, lines and areas. Are there others? What applications might they have?
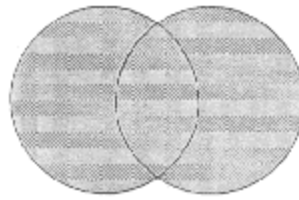
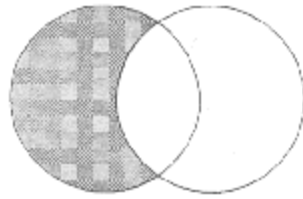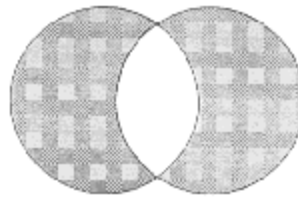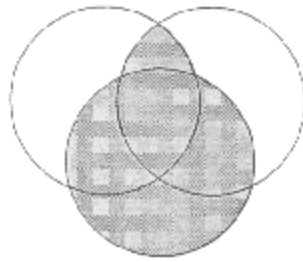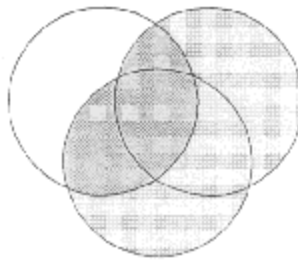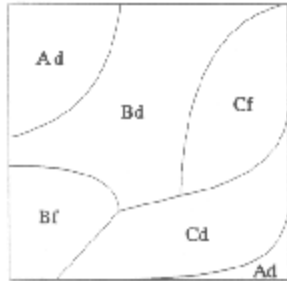*Last Updated: August 30, 1997.*

UNIT 14 IMAGES
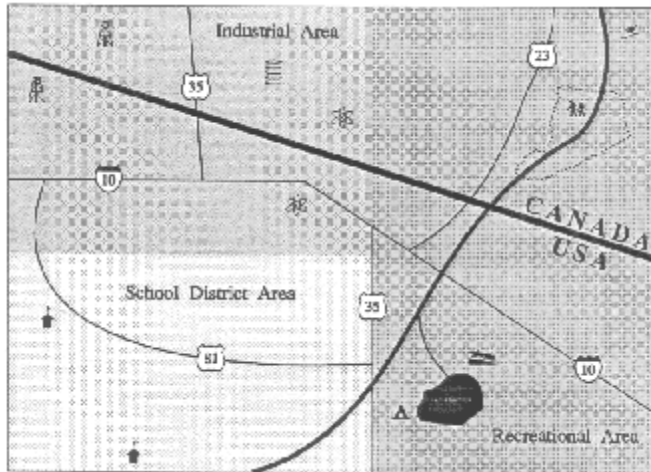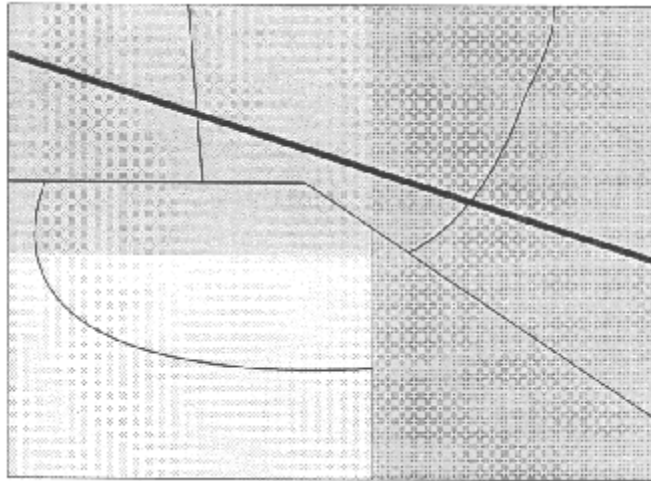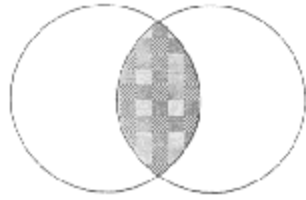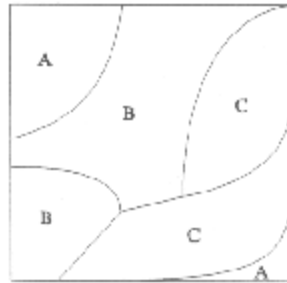
A AND B

A OR B

A NOT B

A XOR B

(A AND B) OR C
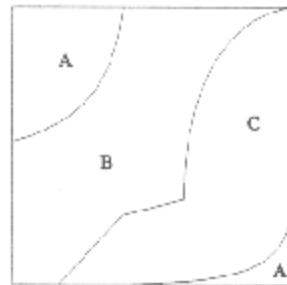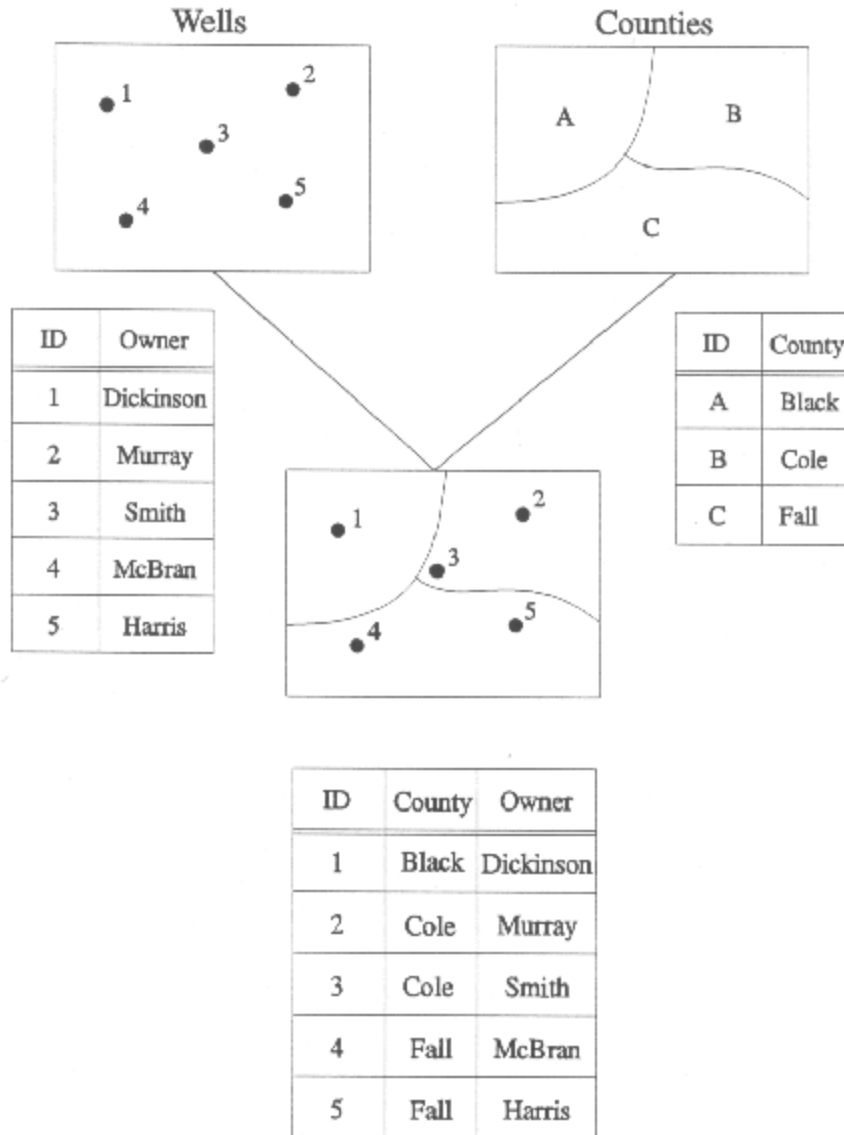
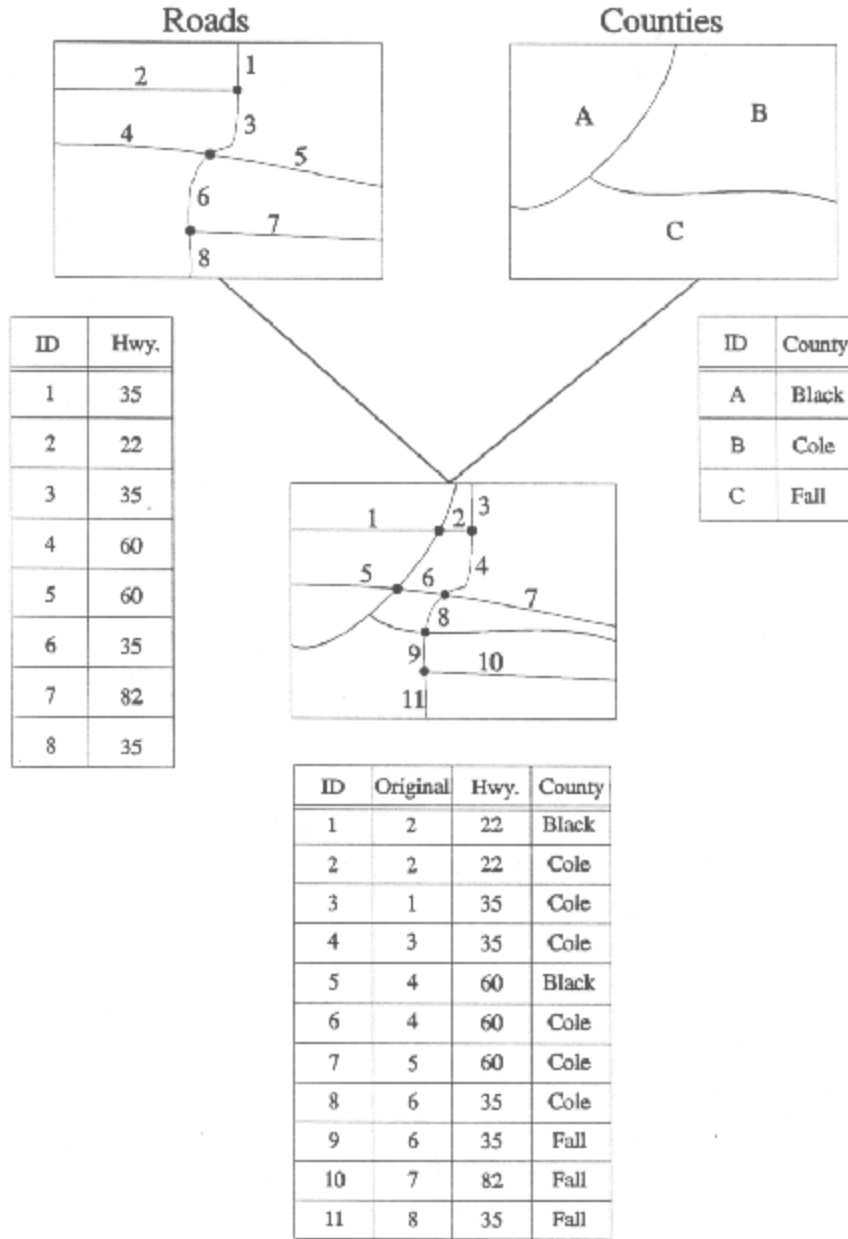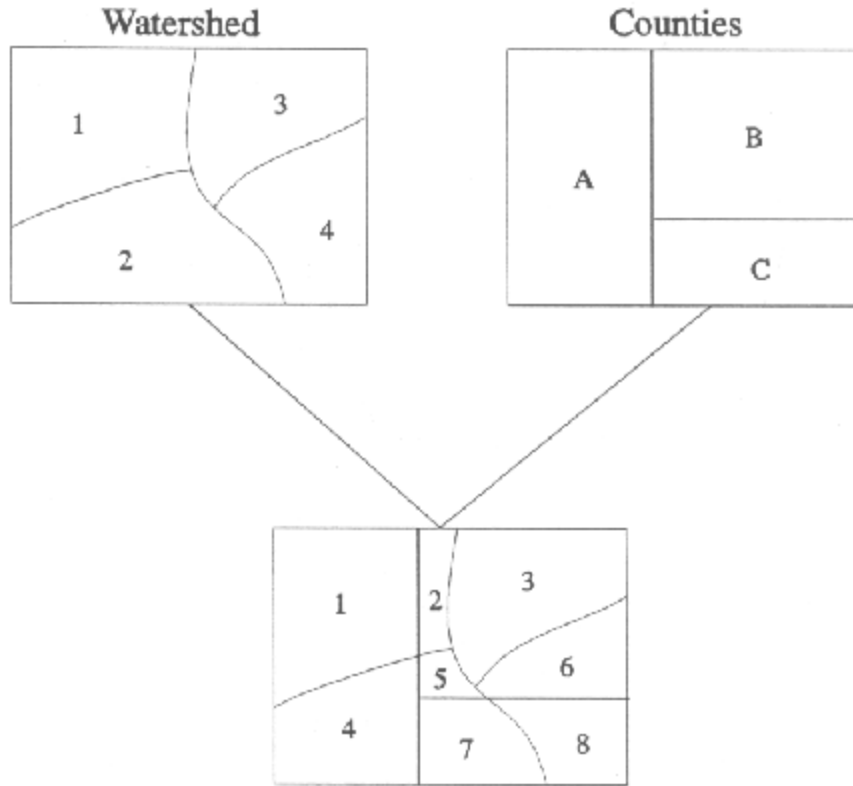A AND (B OR C)

Soil Types A, B and C
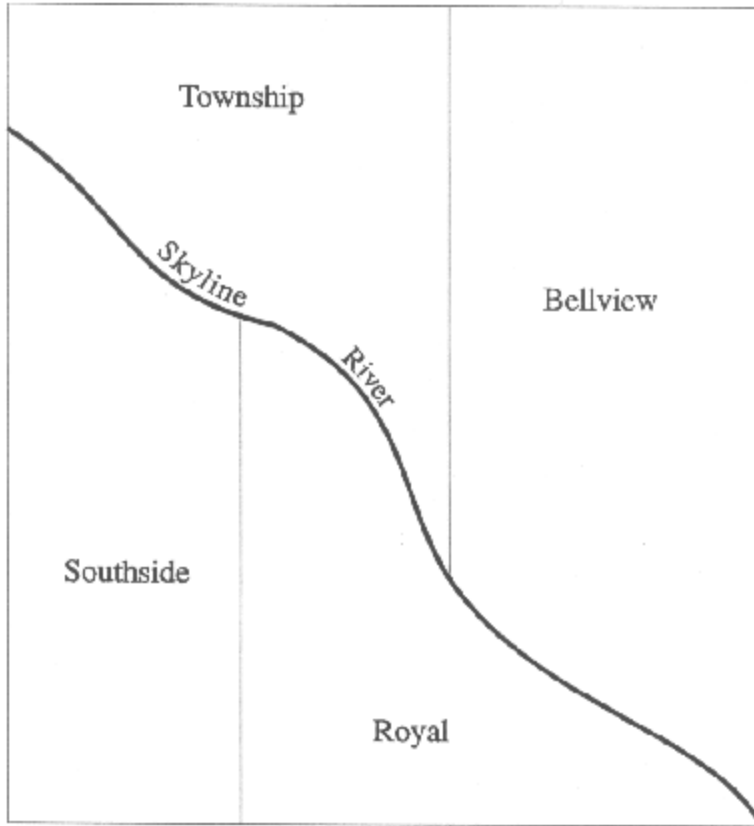with growth potentials d and f

Soil Types A, B and C

Soil Types A, B and C

ID	Owner
1	Dickinson
2	Murray
3	Smith
4	McBran
5	Harris

ID	County
A	Black
B	Cole
C	Fall

ID	County	Owner
1	Black	Dickinson
2	Cole	Murray
3	Cole	Smith
4	Fall	McBran
5	Fall	Harris

Roads

ID	Hwy.
1	35
2	22
3	35
4	60
5	60
6	35
7	82
8	35

Counties

ID	County
A	Black
B	Cole
C	Fall

ID	Original	Hwy.	County
1	2	22	Black
2	2	22	Cole
3	1	35	Cole
4	3	35	Cole
5	4	60	Black
6	4	60	Cole
7	5	60	Cole
8	6	35	Cole
9	6	35	Fall
10	7	82	Fall
11	8	35	Fall

Watershed

Counties

ID	Watershed ID	County ID
1	1	A
2	1	B
3	3	B
4	2	A
5	2	B
6	4	B
7	2	C
8	4	C

| Skyline River | ———— |
| School District Boundaries | |

Skyline River
Census Boundaries
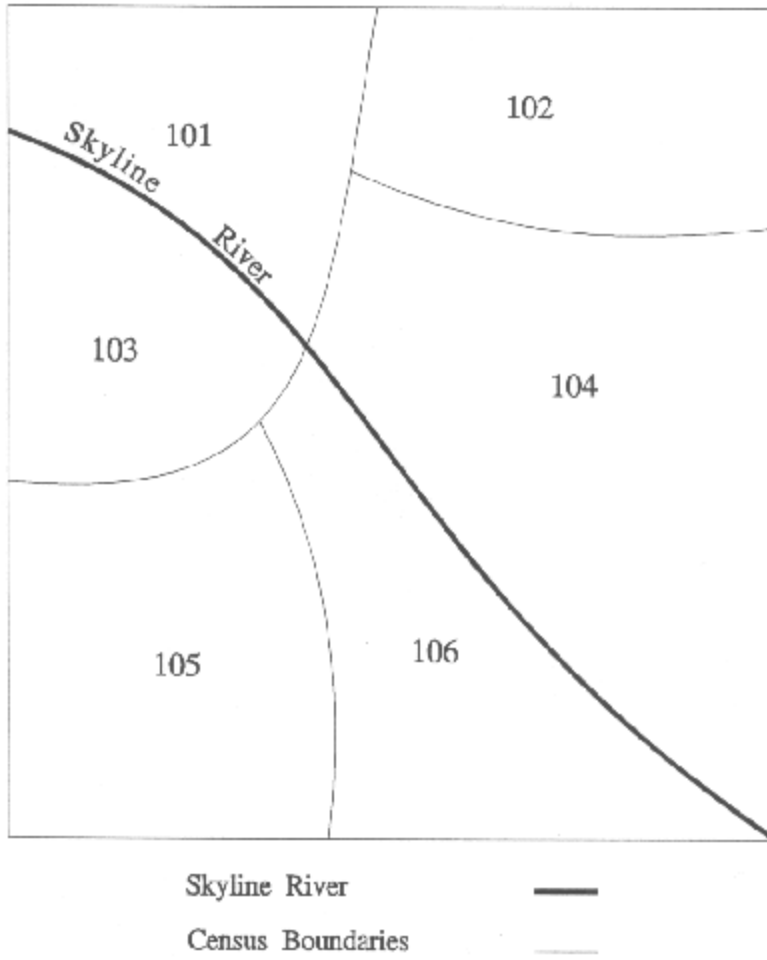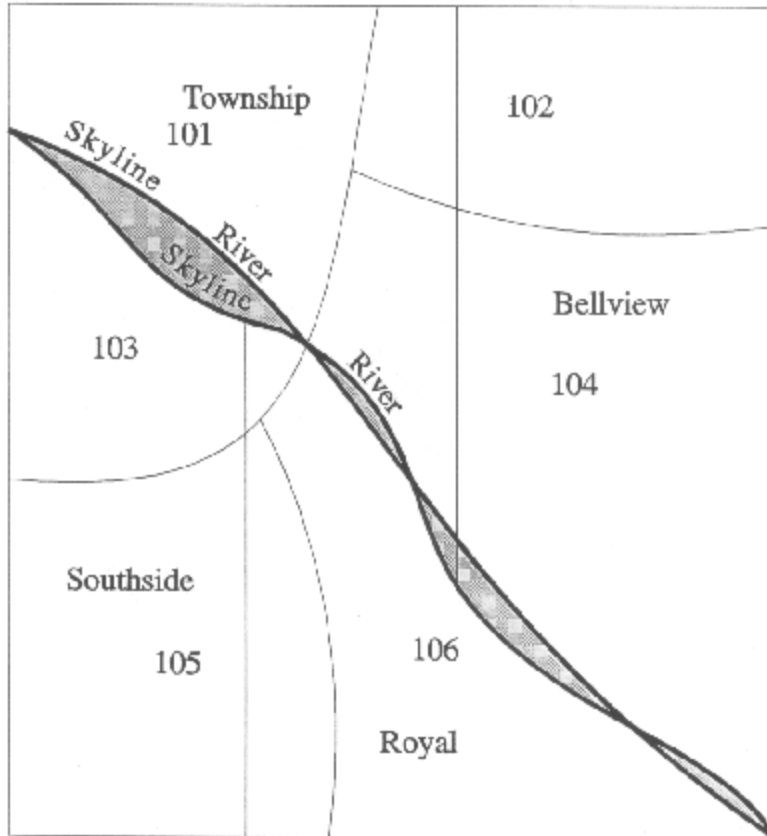
Skyline River ——

Census and School
District Boundaries ——
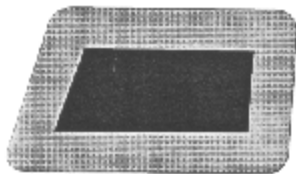
Spurious polygons ⬯

Buffering a Point

eg. All area within one mile of a city.

Buffering a Line

eg. All areas within 1000 meters of a road.

Buffering an Area

eg. All areas within 500 meters of a wetlands area.