



GIS TOOLS



presented by:
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**University of Missouri
Columbia**

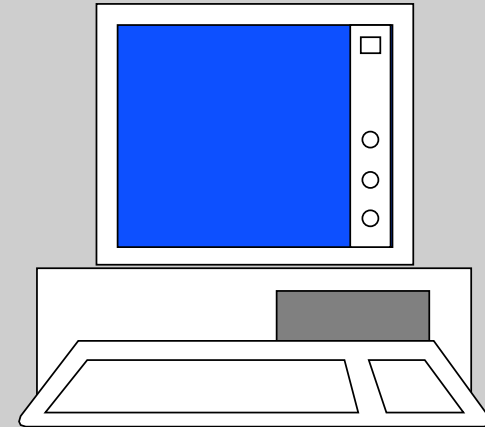
GIS Application Software Components

- Graphics Processing → Map entry, update, editing, display, and hard copy production
- Database Management → Attribute data entry, update, editing, query and reporting
- Basic Cartographic Functions → Area-distance calculation, geographic queries, thematic mapping, overlay, buffer analysis
- Special applications → Network analysis, terrain analysis, neighborhood analysis (districting)
- Application Development → Programming tools for customizing applications

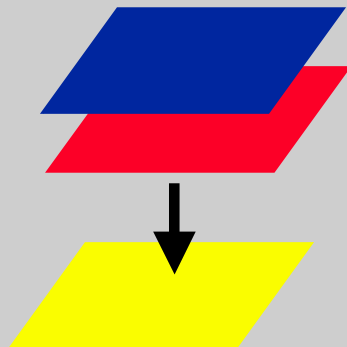
Standard Map Update Production



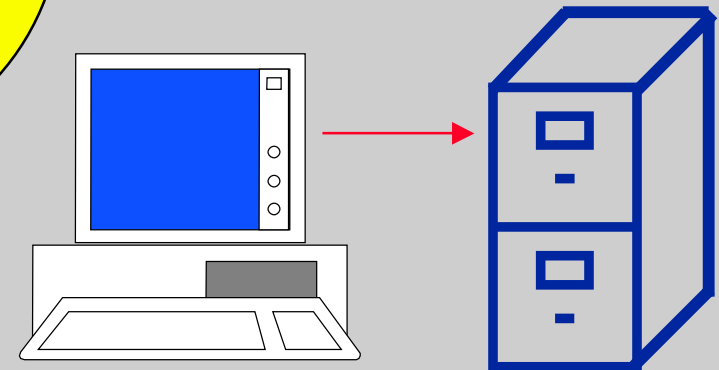
Data Query and Visualization



Major GIS Application Categories



Spatial Analysis



Geographic Index to Detailed Records

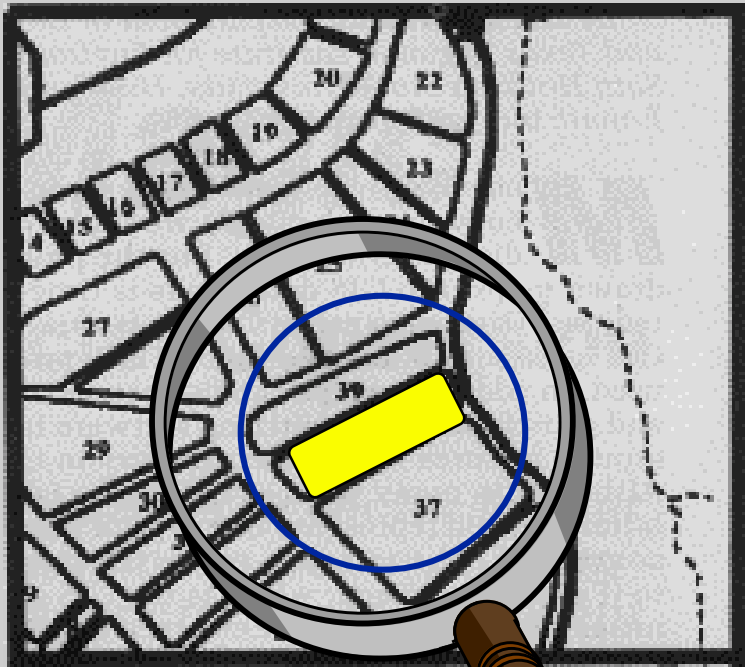
Geographic Query/Reporting

Use of database query and tabular report generation tools to perform special geographic queries and generate hard copy reports, displays, or maps.

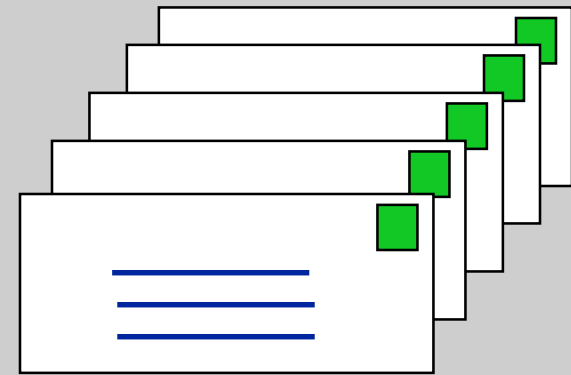
Examples:

- Display and produce tabular summary of all water quality permit sites exceeding discharge standards
- Identify and display all water lines of a specified age and diameter

Using a GIS to Query a Geographic Database



**Proposed Zoning
Change**



Neighbors must be notified

Selecting Records

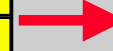
		TYPE
		30
		30
		27
		16
		30
		27



		TYPE
		30
		30
		27
		16
		30
		27



		TYPE
		30
		30
		27
		16
		30
		27



		TYPE
		30
		30
		27
		16
		30
		27

RESELECT

Reselect Type = 30
3 records selected

ASELECT

Aselect Type = 16
4 records selected

or

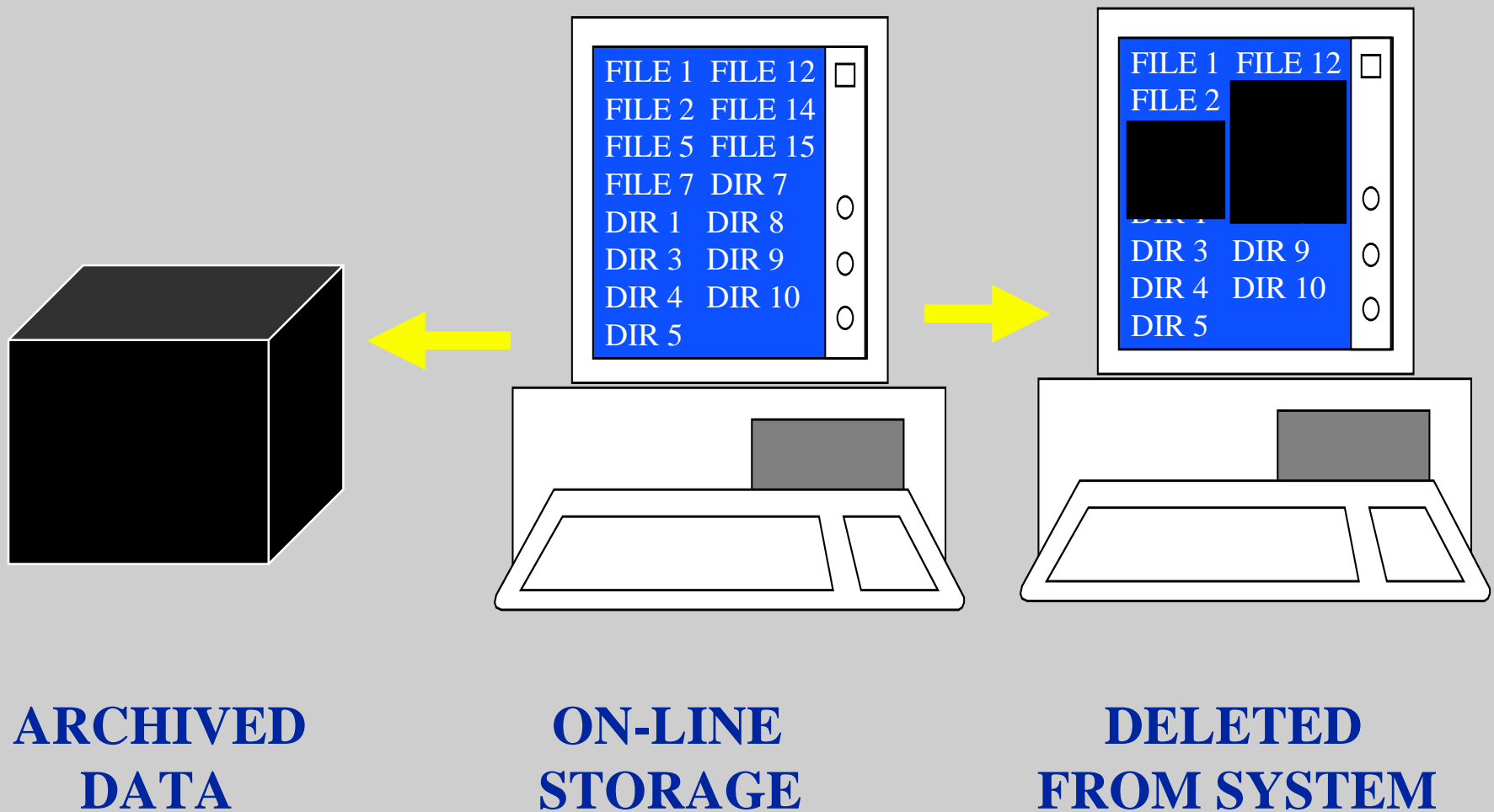
ASELECT

6 records selected

NSELECT

2 records selected

GIS Functions - Data Management



Thematic Mapping

Production of maps in which a shading pattern is used to differentiate between categories of a geographic “theme” for a defined map or feature.

Examples:

- ✘ Shaded land use maps
- ✘ Population density maps

Spatial Aggregation

The retrieval and tabulation of map features or occurrences that are encompassed by a user-defined area.

Examples:

- ➔ Summary of crime incidents by police reporting district
- ➔ Calculation of newly paved road mileage within a state highway maintenance district

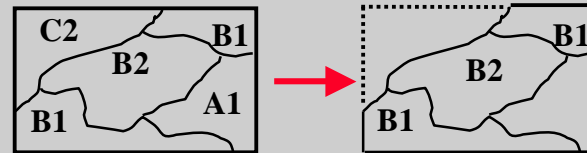


Logical Operators Spatial Results

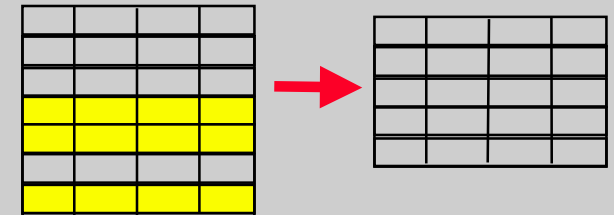
Tabular Results

RESLECT

Selection by logical expressions



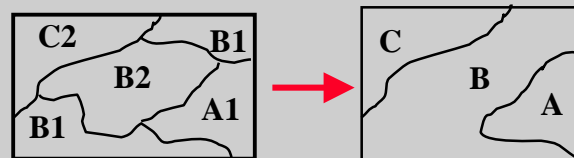
Subset of existing features
(same features, but fewer of them)



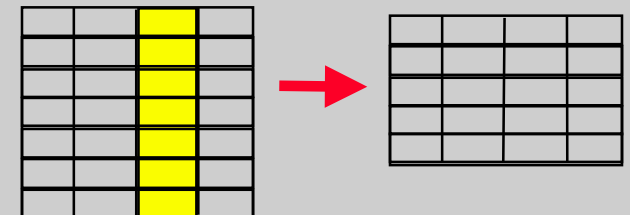
Subset of records
(same items & same values, but fewer records)

DISSOLVE (one item)

Selection by item



Polygons with same values merge
(fewer polygons)



Item Reduction
(less items, fewer records, new User-IDs & adjusted areas)

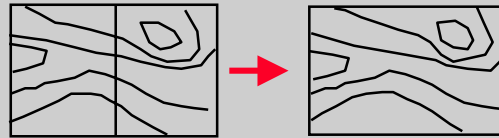
Logical Operators

Spatial Results

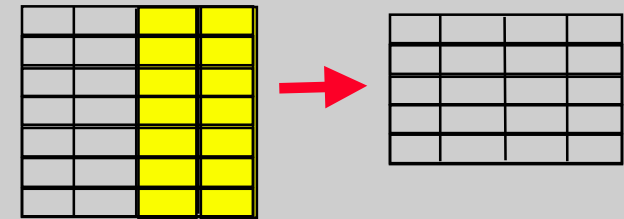
Tabular Results

DISSOLVE (all items)

Selection by #ALL
option



Polygons with same
values merge
(fewer polygons)

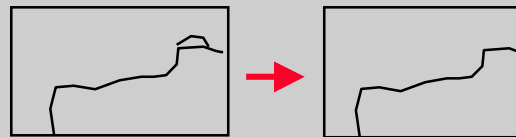


Item Reduction

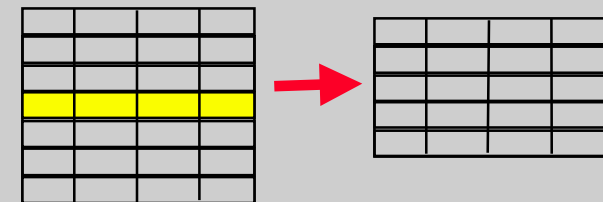
(same items, fewer records,
areas adjusted & feature IDs
can be maintained or offset.)

ELIMINATE

Selection by logical
expressions



Polygons merged to
neighbor by removing
longest shared border
(fewer polygons)



Record Reduction

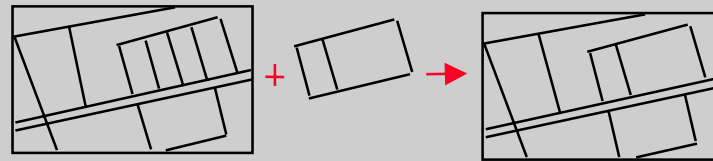
(same items, fewer records,
(areas adjusted & User-IDs of
eliminated polygons are deleted)

Boundary Operations

Spatial Results

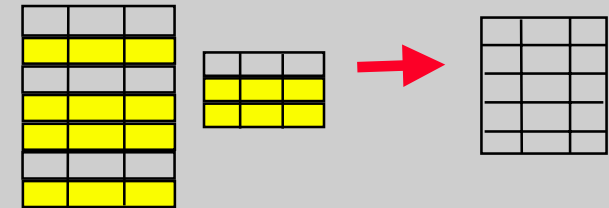
Tabular Results

UPDATE POLY NET



Replace existing polygons

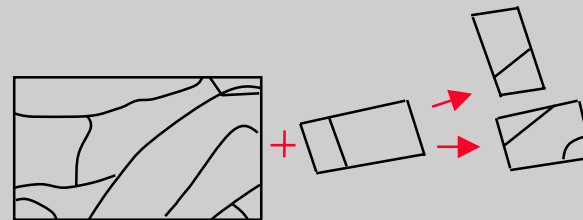
- ~ external polygon boundary is used to 'cut & paste' new features
- ~ updating uses topological



Replaces old records

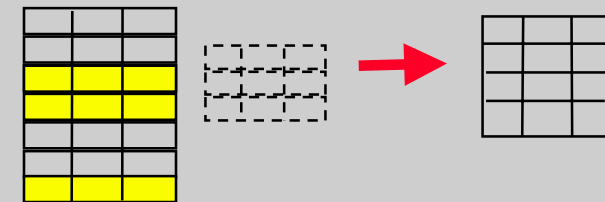
- ~ attributes in [update_cover] must match [in_cover]
- ~ User-IDs are renumbered (unique values)

SPLIT POLY LINE POINT NET LINK



Subset of existing features

- ~ retains features inside internal polygon boundaries
- ~ splitting uses topological overlay



Subset of records

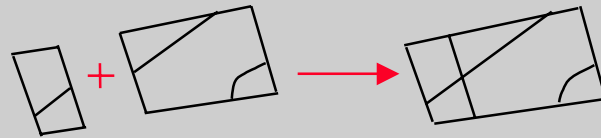
- ~ same attributes as [in_cover] but fewer records, areas adjusted & User-IDs are renumbered (unique values)

Boundary Operations

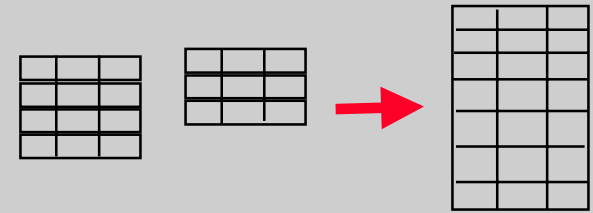
Spatial Results

Tabular Results

MAPJOIN POLY NET

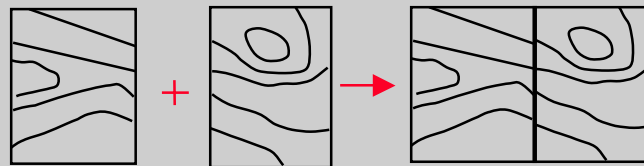


Merge Adjacent polygons
~ polygons from many coverages
are combined, including their
borders

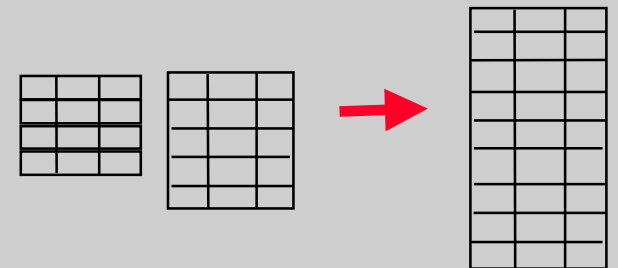


Records are Combined
~ attributes in all coverages being
combined must match
~ User-IDs can be offset or remain
the same (Duplicate values possible)

APPEND POLY LINE POINT NET LINK



**Merge similar features
adjacent or coincident**
~ features from several coverages
are combined
~ topology must be reestablished
with CLEAN or BUILD



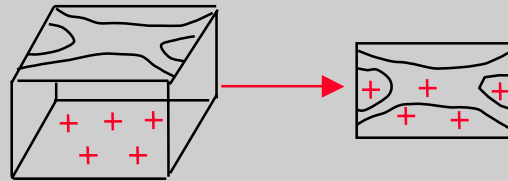
Records are Combined
~ attributes in all coverages being
combined must match
~ User-IDs can be offset or remain
the same (Duplicate values possible)

Boundary Operations

Spatial Results

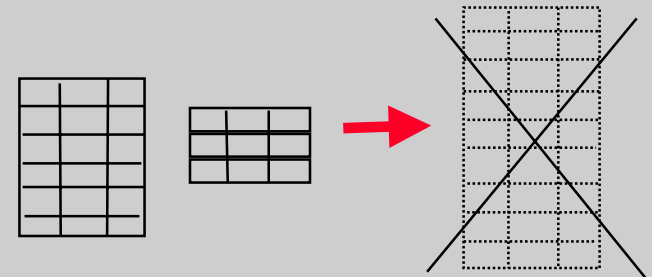
Tabular Results

APPEND (all types)
NO TEST option



Merge different features -
adjacent or coincident

- ~ features from several coverages
are combined
- ~ topology must be reestablished
with CLEAN or BUILD



Feature attributes are lost

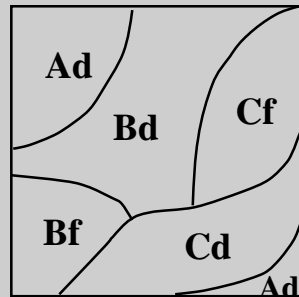
- ~ attributes do not matter because
they are not appended

Reclassify, Dissolve, & Merge

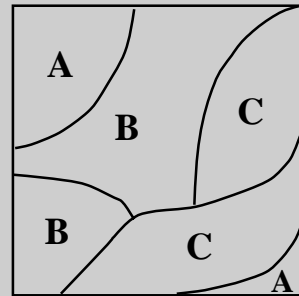
- The operations are used frequently in working with area objects
 - These are used to aggregate areas based on attributes
- Consider a soils map:
 - We wish to produce map of major soil types from a layer that has polygons based on much more finely defined classification scheme

Steps:

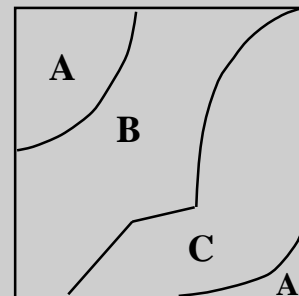
1. **Reclassify** soil areas by soil type only.
2. **Dissolve** boundaries between areas of same soil type.
3. **Merge** polygons into large objects.



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



Soil Types A, B and C



Soil Types A, B, and C

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

Polygon Overlay

The vertical overlay of multiple map layers to derive a resulting map layer based on some logical combination of attributes from the original layers.

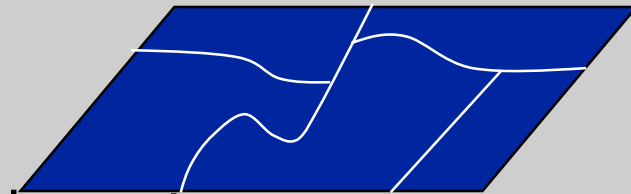
Examples:

- ✗ Erosion analysis based on overlay of soil, slope, and land cover layer;
- ✗ Determine parcels that fall within flood prone areas
- ✗ Site suitability for industrial development



Suitability Analysis Using Map Overlays

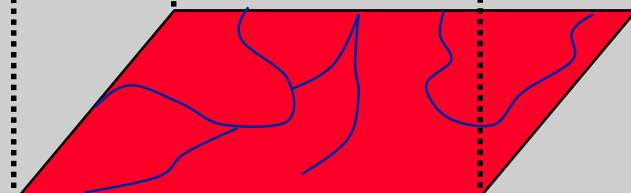
Governmental
Administrative
Units



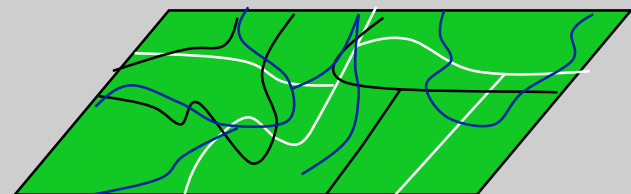
Land Use



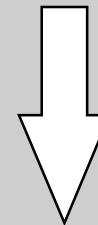
Soils



Suitability for
Industrial
Development



Analysis
of these
interrelated
maps



Produces



Application
(Result)

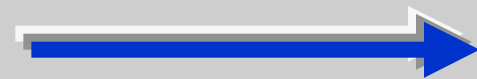
Topological Overlay (continued)

- Relationships are updated for the new, combined map
- Result is information about relationships (new attributes) for the old (input) maps rather than the creation of new objects
 - Ex: overlay map of school districts on census tracts
 - Result is map showing every school district/census tract combination
 - For each combo, the database contains an area objects
 - 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



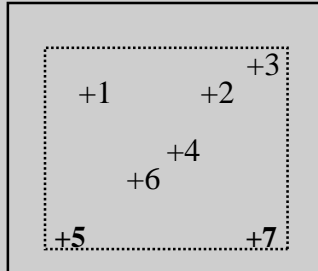
Point in Polygon

- Overlay point objects on areas, compute “is contained in” relationship
- Result is a new attribute for each point
 - Example: combine wells and planning districts, find district containing each well

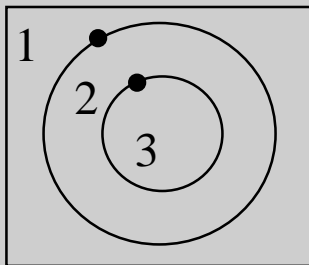


Identity - Point Option

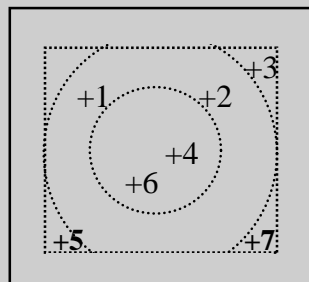
Input Coverage



Identity Coverage



Output Coverage



INPUT COVERAGE	
#	Attribute
1	A
2	B
3	C
4	D
5	E
6	F
7	G

IDENTITY COVERAGE	
#	Attribute
1	
2	102
3	103

OUTPUT COVERAGE		INPUT COVERAGE		IDENTITY COVERAGE	
#	Attribute	#	Attribute	#	Attribute
1	A	1	A	2	102
2	B	2	B	2	102
3	C	3	C	1	
4	D	4	D	3	103
5	E	5	E	1	
6	F	6	F	3	103
7	G	7	G	1	

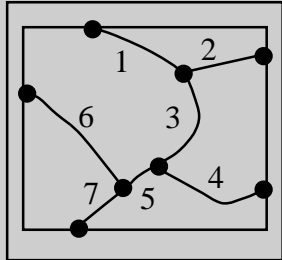
Line on Polygon

- Overlay line objects on area objects, compute “is contained in” relationships
- 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
 - Example: combine roads and counties, find county containing each road segment

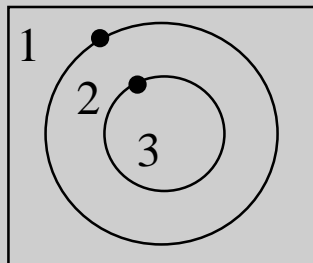


Identity - Line Option

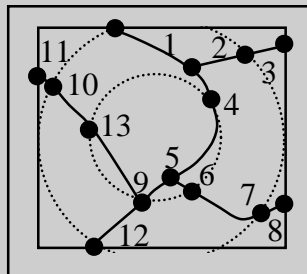
Input Coverage



Identity Coverage



Output Coverage



INPUT COVERAGE	
#	Attribu
1	A
2	B
3	A
4	C
5	A
6	D
7	A

UNION COVERAGE	
#	Attribu
1	
2	102
3	103

OUTPUT COVERAGE		INPUT COVERAGE		UNION COVERAGE	
#	#	Attribu	#	Attribu	
1	1	A	2	102	
2	2	B	2	102	
3	2	B	1		
4	3	A	2	102	
5	3	A	3	103	
6	4	C	3	103	
7	4	C	2	102	
8	4	C	1		
9	5	A	3	103	
10	6	D	2	102	
11	6	D	1		
12	7	A	2	102	
13	6	D	3	103	

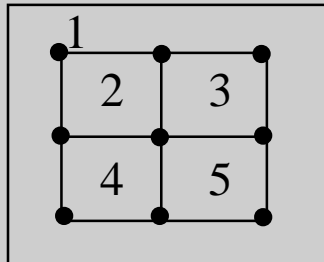
Polygon on Polygon

(“Polygon Overlay”)

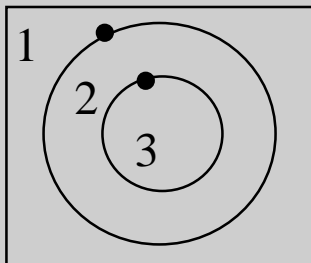
- Overlay two layers of area objects
- Boundaries are broken at each intersection
- Number of output areas likely greater than the total number of input areas
 - Example: input watershed boundaries, county boundaries, output map of watershed/county combinations
 - After overlay we can recreate either of the input layers by dissolving and merging based on the attributes contributed by the input layer

Identity - Poly Option

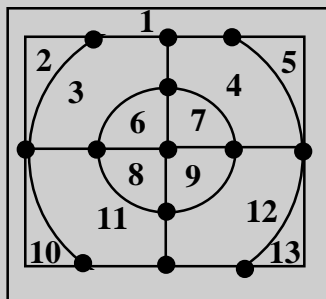
Input Coverage



Identity Coverage



Output Coverage



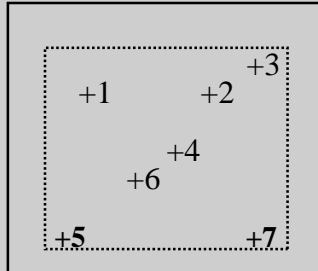
INPUT COVERAG	
#	Attribute
1	
2	A
3	B
4	C
5	D

IDENTITY COVERAC	
#	Attribute
1	
2	102
3	103

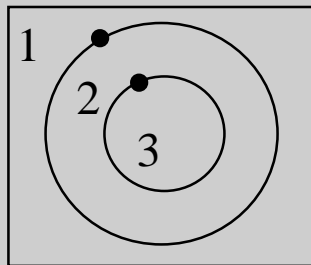
OUTPUT COVERAG	INPUT COVERAC	IDENTITY COVERAC
#	#	Attribute
1	1	
2	2	A
3	2	A
4	3	B
5	3	B
6	2	A
7	3	B
8	4	C
9	5	D
10	4	C
11	4	C
12	5	D
13	5	D

Intersect - Point Option

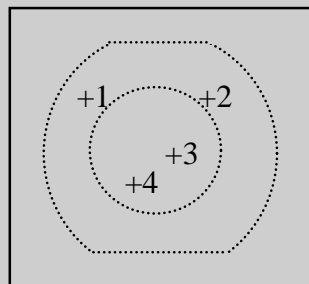
Input Coverage



Intersect Coverage



Output Coverage



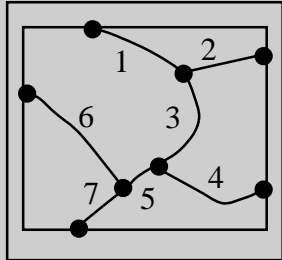
INPUT COVERAGE	
#	Attribute
1	A
2	B
3	C
4	D
5	E
6	F
7	G

INTERSECT COVERAGE	
#	Attribute
1	
2	102
3	103

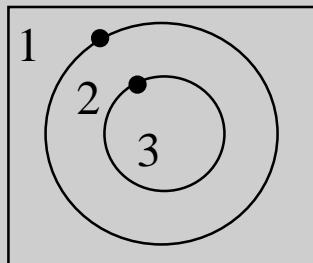
OUTPUT COVERAGE		INPUT COVERAGE		INTERSECT COVERAGE	
#	Attribute	#	Attribute	#	Attribute
1		1	A	2	102
2		2	B	2	102
3		4	D	3	103
4		6	F	3	103

Intersect - Line Option

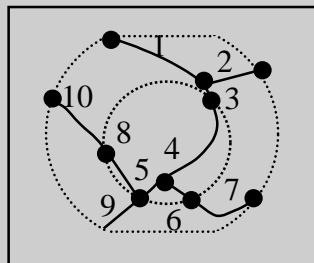
Input Coverage



Intersect Coverage



Output Coverage



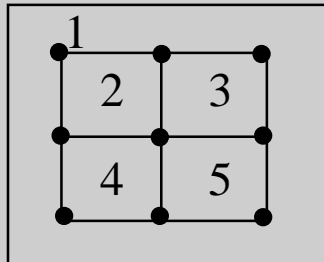
INPUT COVERAGE	
#	Attribute
1	A
2	B
3	A
4	C
5	A
6	D
7	A

INTERSECT COVERAGE	
#	Attribute
1	
2	102
3	103

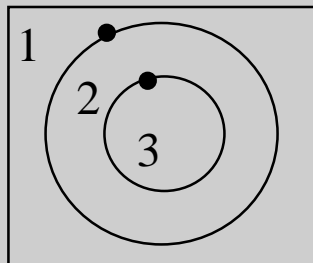
OUTPUT COVERAGE		INPUT COVERAGE		INTERSECT COVERAGE	
#	Attribute	#	Attribute	#	Attribute
1	A	1	A	2	102
2	B	2	B	2	102
3	A	3	A	2	102
4	A	3	A	3	103
5	A	5	A	3	103
6	C	4	C	3	103
7	C	4	C	2	102
8	D	6	D	3	103
9	A	7	A	2	102
10	D	6	D	2	102

Intersect - Poly Option

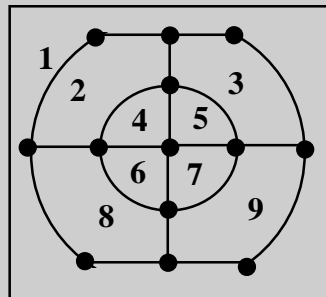
Input Coverage



Intersect Coverage



Output Coverage



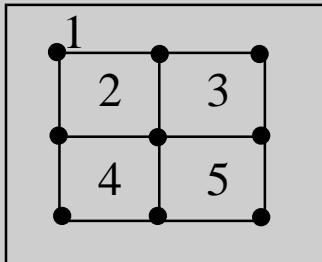
INPUT COVERAG	
#	Attribute
1	
2	A
3	B
4	C
5	D

INTERSECT COVERAG	
#	Attribute
1	
2	102
3	103

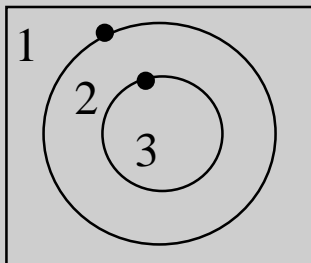
OUTPUT COVERAG		INPUT COVERAG		INTERSECT COVERAG	
#		#	Attribute	#	Attribute
1		1		1	
2		2	A	2	102
3		3	B	2	102
4		2	A	3	103
5		3	B	3	103
6		4	C	3	103
7		5	D	3	103
8		4	C	2	102
9		5	D	2	102

Union

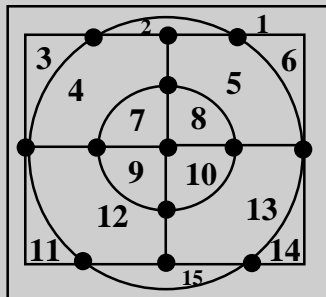
Input Coverage



Union Coverage



Output Coverage



INPUT COVERAGE	
#	Attribute
1	
2	A
3	B
4	C
5	D

UNION COVERAGE	
#	Attribute
1	
2	102
3	103

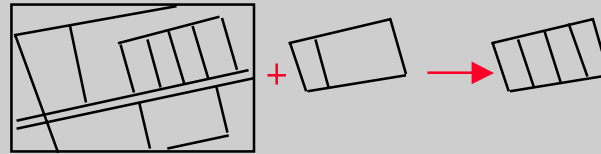
OUTPUT COVERAGE	INPUT COVERAGE	UNION COVERAGE
#	# Attribute	# Attribute
1	1	1
2	1	2 102
3	2 A	1
4	2 A	2 102
5	3 B	2 102
6	3 B	1
7	2 A	3 103
8	3 B	3 103
9	4 C	3 103
10	5 D	3 103
11	4 C	1
12	4 C	2 102
13	5 D	2 102
14	5 D	1
15	1	2 102

Boundary Operations

Spatial Results

Tabular Results

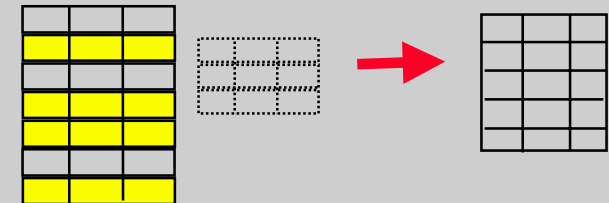
CLIP
POLY
LINE
POINT
NET
LINK



Subset of existing features

~ retains features inside the external polygon boundary

~ clipping uses topological overlay

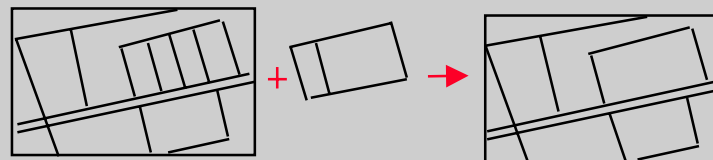


Subset of records

~ same attributes as [in_cover]
but fewer records, areas adjusted
& User-IDs are renumbered
(unique values)

ERASECOV

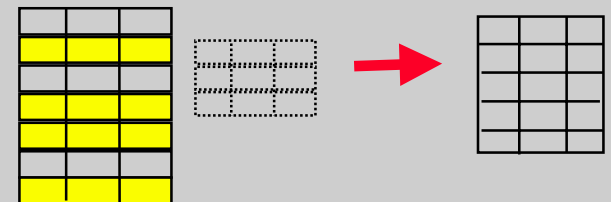
POLY
LINE
POINT
NET
LINK



Subset of existing features

~ erases features inside the external polygon boundaries

~ erasing uses topological overlay



Subset of records

~ same attributes as [in_cover]
but fewer records, areas adjusted
& User-IDs are renumbered
(unique values)

GIS Functions - Manipulation and Analysis

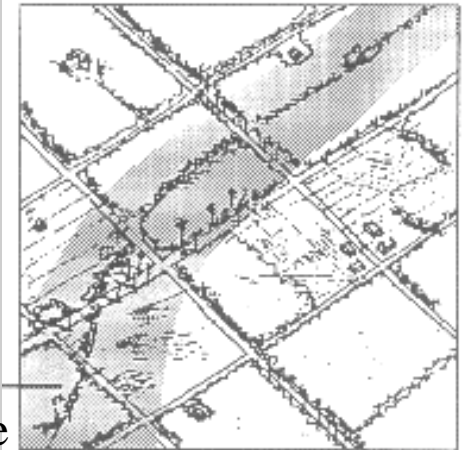
River



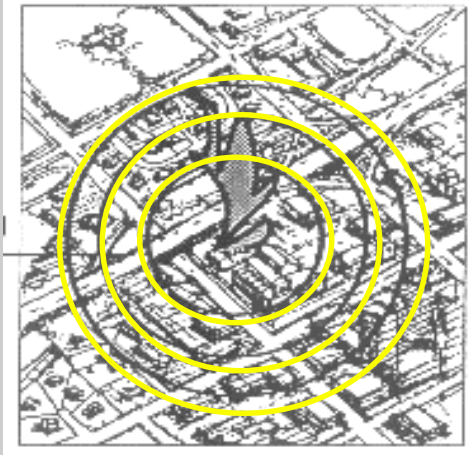
Factory



100-year
Flood zone



Areas affected
by chemical
explosion



Parcels susceptible to flooding

Impact of Events

Buffering

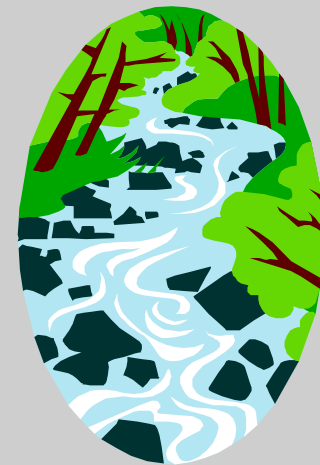
- A buffer can be constructed around a point, line or area
- Buffering creates a new area, enclosing the buffered object
 - Protected zones around lakes and streams
 - Zone of noise pollution around highways
 - Service zone around bus route (ex: 300 m walking distance)
 - Groundwater pollution zone around waste site

Proximity/Buffer Analysis

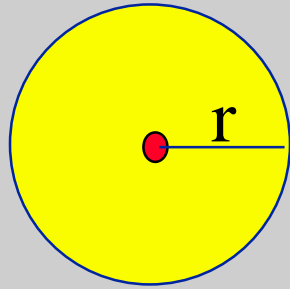
Generation and selection of map data within specified distance around a point, line, or polygon feature

Examples:

- Property search to find all parcels within a specified distance of a target parcel
- Environmental impact analysis requiring delineation of a buffer zone around a stream



Buffering



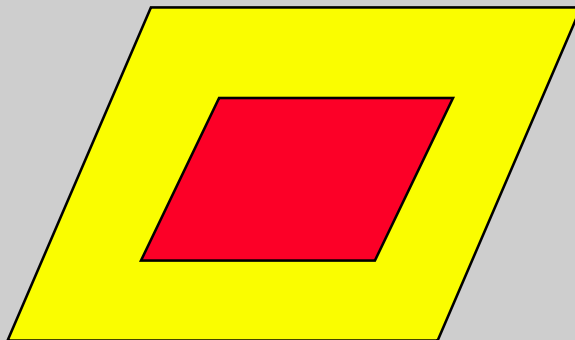
Buffering a Point

example: All area within one mile of the city.



Buffering a Line

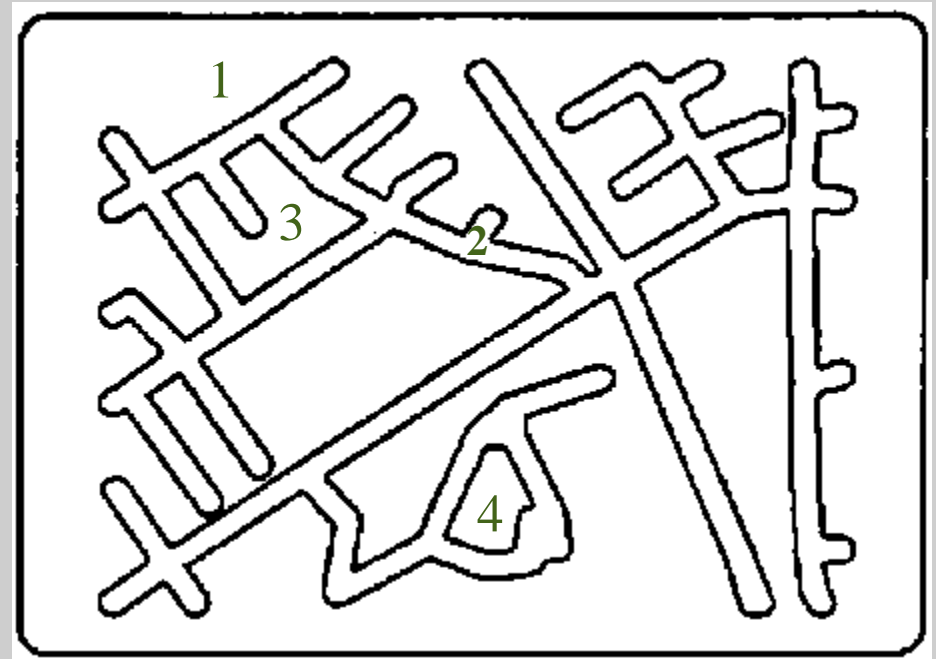
example: All areas within 1000 meters of a road.



Buffering an Area

example: All areas within 500 meters of a wetlands area.

Buffer

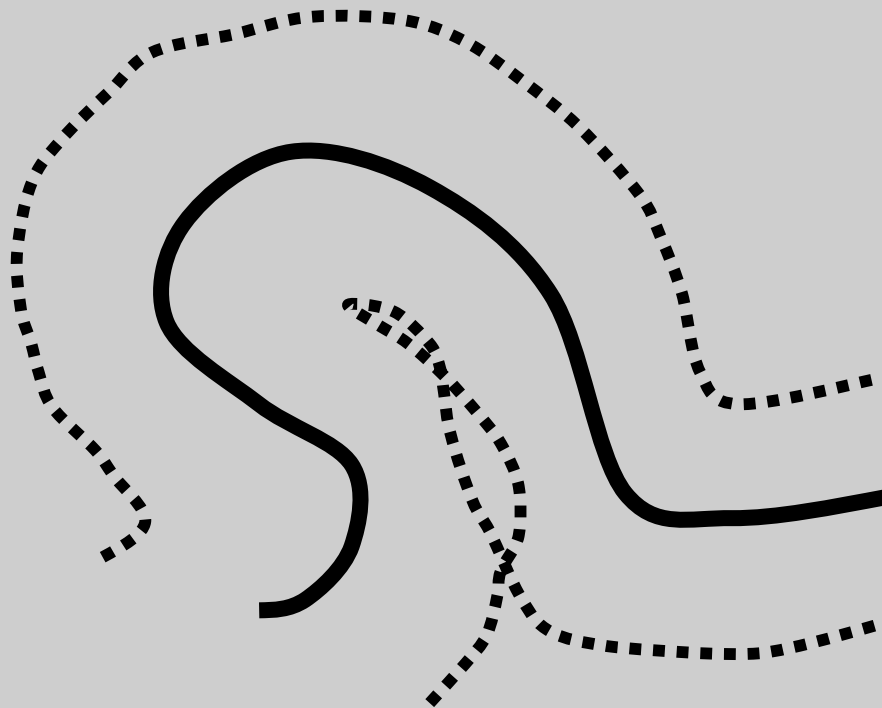


Buffering (continued)

- Options available for raster, such as a “friction” layer, do not exist for vector
- Sometimes, width of the buffer can be determined by an attribute of the object
 - Example: 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

Buffering (continued)

- Buffering is much more difficult in vector from the point of view of the programmer
- Problems with buffer operations may occur when buffering very convoluted lines or areas:



Network Analysis

Analytical technique to evaluate flow or paths through a defined linear network.

Examples:

- Analysis of optimal routes through road network
- Analysis of flow in a water distribution system



Address Matching and Incident Mapping

Generation of maps showing the point location of features or phenomena on a suitable base map. Incident locations may be defined by x, y coordinate, street address, or other locational identifier.

Examples:

- Mapping of water sampling points
- Police incident mapping



Terrain Analysis

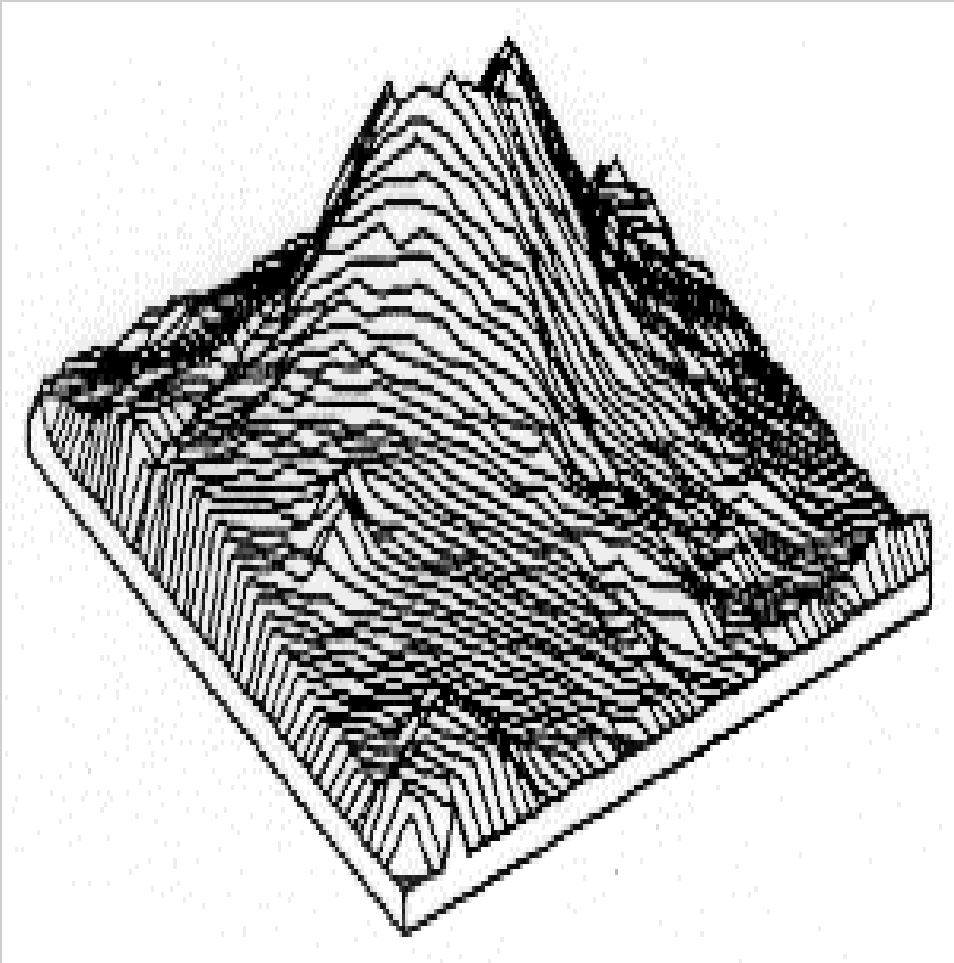
Use of three-dimensional data to perform landscape or terrain evaluation.

Examples:

- ➔ Use of digital elevation models to generate contour maps and perform slope analysis
- ➔ Civil engineering calculations to determine cut-and-fill volumes and generate vertical profile drawings



What is a Surface?



- ✓ A surface is a continuous feature, without discrete intervals.
- ✓ There is no way to store all the information about a surface.
- ✓ We must **approximate** a surface with **samples**.

Surface Data

A 3-D model of the surface is generated from a TIN, lattice, or vector contour file.

Most models are based on point data which associates a z value item with an x,y location.

The z value usually measures surface elevation and provides the surface model with its third dimension.

These values can also be used to represent a wide variety of measurements. Common examples are: depth, temperature, rainfall, pollutants, barometric pressure and demographic distribution.

Surfaces which are generated to represent these data points become the model upon which to perform surface analysis.

Surface Analysis

Can be performed to answer any of the following questions.

- ? What is the elevation of a selected point on the surface?
- ? Can specified points see each other?
- ? What are the real distances traveled along the surface?
- ? How much area does a region of the surface really cover?
- ? What is the area lying below a profile of the surface?
- ? How much space does the surface model occupy?
- ? How steep are different areas of the surface?
- ? Which direction does each area face?
- ? Which regions have a similar elevation?
- ? What climatic patterns can be generated?
- ? Where should the boundaries between centers be located?

Elevation Represented as Points

Tiefert Mountains, California

Lattice description for smlat22

Lattice size and origin

Points X/Y = 21 21

Origin (x,y) = 540000.00

3911940.000

Lattice distance between points:

Distance in X = 30.000

Distance in Y = 30.000

Surface value in range:

Min z=235.000

Max z=631.00

Lattice boundary:

Xmin=540000.000

Xman= 540600.000

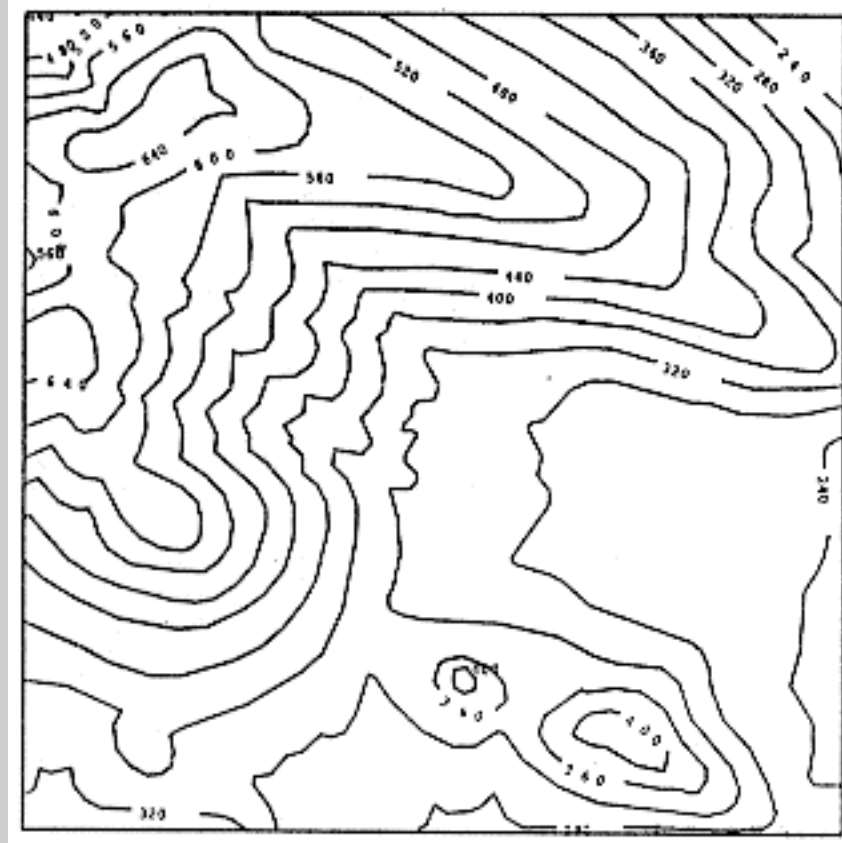
Ymin= 3911940.000

Ymax = 3912540.000

456	485	521	555	574	571	550	526	505	484	462	442	423	403	382	357	327	296	268	248	235
501	529	565	596	610	590	578	558	538	518	496	474	454	434	413	389	361	330	298	269	246
552	577	608	626	624	614	598	581	565	548	530	509	489	467	445	422	397	368	336	301	269
580	606	623	625	615	601	589	579	571	563	553	536	521	501	478	455	430	401	366	329	292
579	606	615	609	592	573	559	550	548	546	544	538	531	518	500	479	451	417	380	342	304
570	596	602	592	575	551	528	514	506	505	509	507	506	503	494	477	453	420	383	346	309
578	597	599	586	564	538	509	484	467	458	458	458	459	461	459	453	441	420	392	359	322
605	616	607	584	556	525	495	464	434	414	406	406	405	406	407	409	410	407	395	373	342
631	629	611	580	545	511	480	448	415	386	367	361	356	353	352	355	362	370	373	366	349
630	624	603	570	529	491	459	430	398	367	343	331	323	316	312	312	317	324	331	332	324
609	603	587	556	518	479	442	411	383	354	330	317	305	296	290	288	288	290	293	292	285
572	574	572	555	525	486	446	409	376	347	324	310	298	288	281	276	274	272	271	268	260
530	542	556	556	537	504	462	418	377	345	321	306	294	284	277	272	267	263	260	256	250
491	510	531	543	534	507	466	420	377	342	319	304	291	282	274	269	264	260	256	252	245
457	475	495	509	507	486	452	411	371	339	318	307	295	286	278	271	265	261	257	250	242
424	439	455	466	466	452	427	395	364	342	328	319	312	303	293	284	276	268	260	250	240
394	405	418	427	427	417	398	375	355	343	344	344	340	328	319	311	299	284	266	251	240
370	377	388	395	395	385	371	355	340	336	345	353	347	347	351	350	333	303	275	255	242
351	355	365	372	370	360	349	337	327	324	335	334	338	350	367	375	359	328	293	265	246
336	338	346	352	349	342	333	323	316	314	313	312	317	331	348	360	358	336	306	276	254
322	323	327	330	330	327	321	315	308	302	297	294	296	304	313	320	321	313	295	275	258

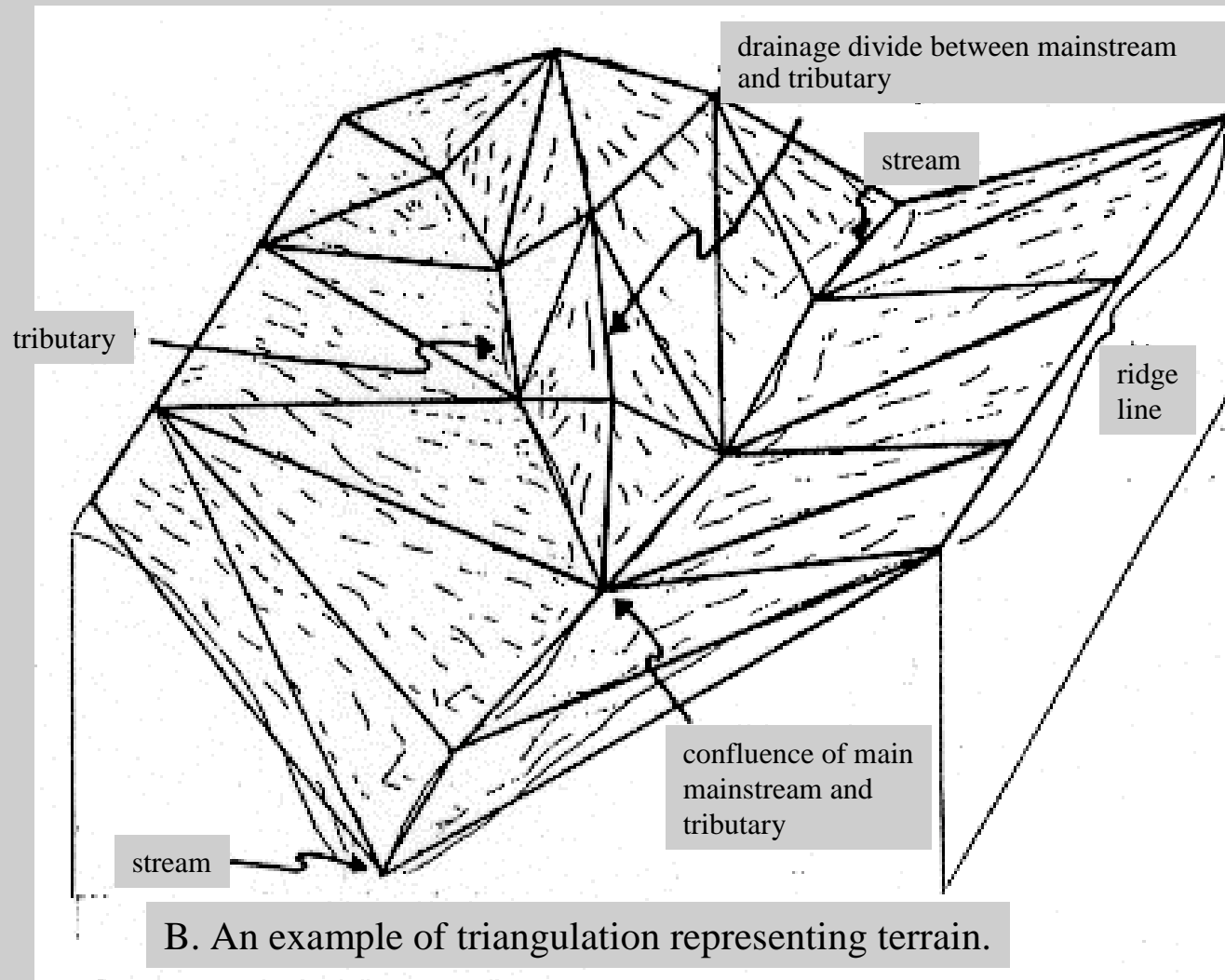
Elevation Represented as Lines

Tiefort Mountains, California



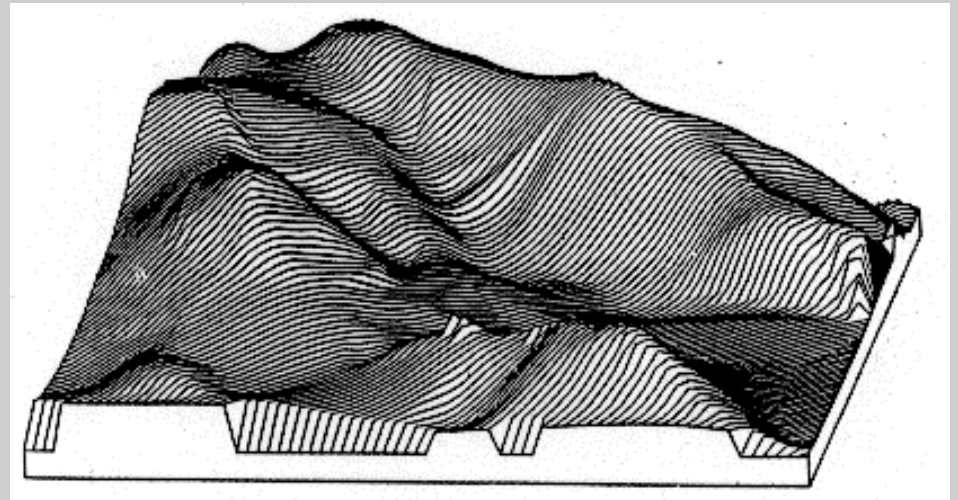
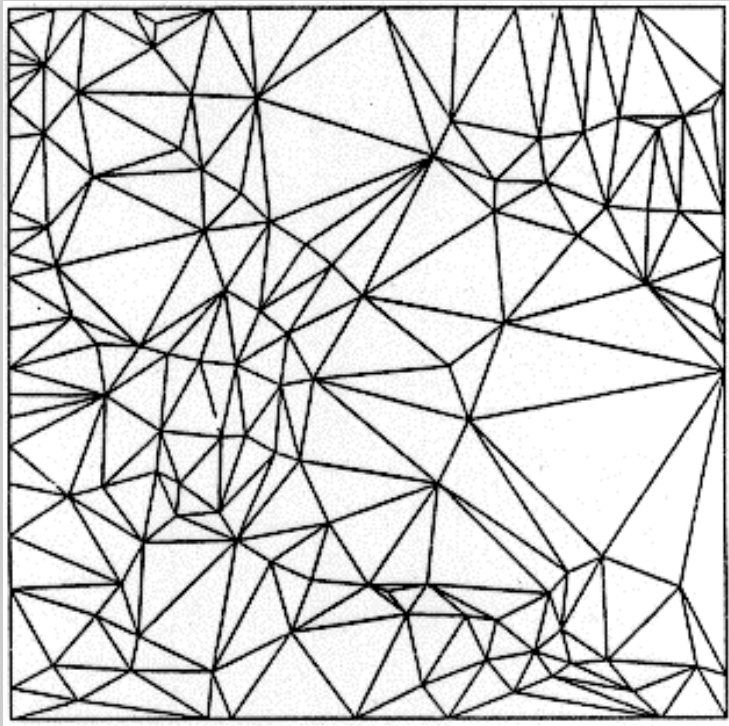
Triangulation of a Terrain Surface

Source: Heil, R.J. and S.M. Brych, "An approach for consistent topographic representation of varying terrain", *Proceedings of the Digital Terrain Models (DTM) Symposium*, Falls Church, VA: ASP and ACSM, 1978, p. 408, Figure 4b.



Elevation Represented as Areas

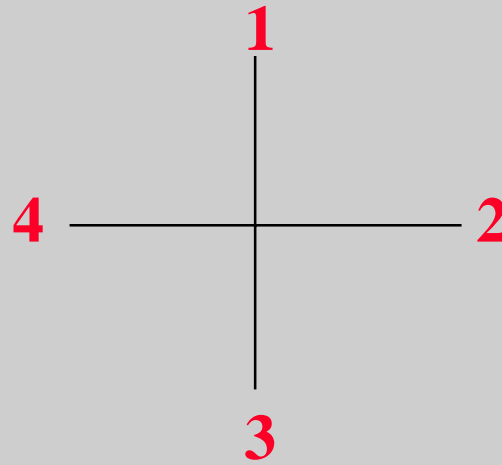
Tiefort Mountains, California



Flow Direction Example

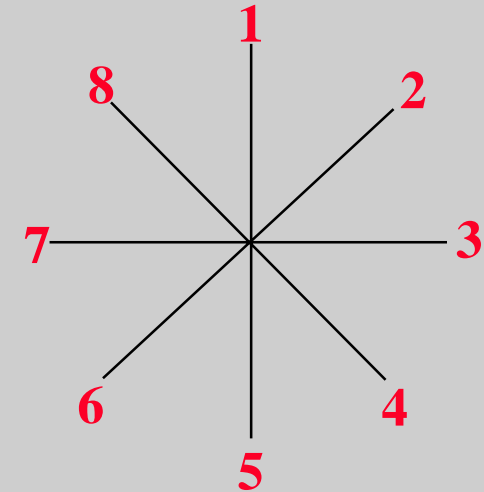
DEM:

10	9	11	12
8	7	6	7
5	4	3	4
5	0	1	5



4 moves

3	3	3	3
3	3	3	3
2	3	3	4
2	0	4	4

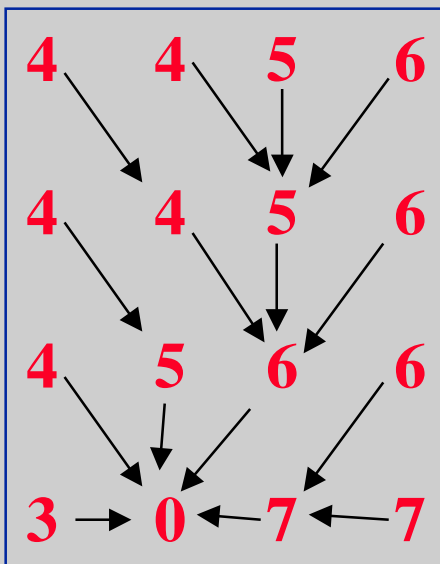


8 moves

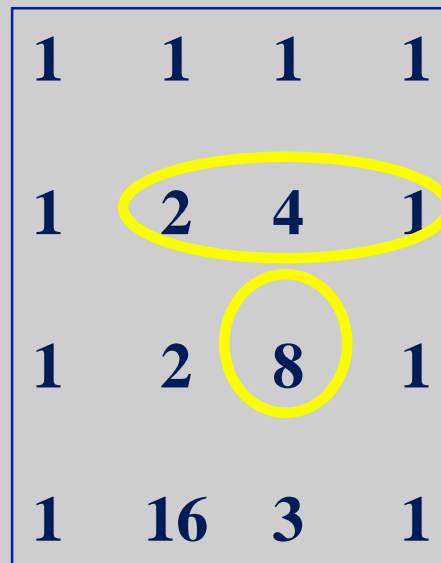
4	4	5	6
4	4	5	6
4	5	6	6
3	0	7	7

Determining the Network

Flow Directions



Accumulating Flow



Critical Flow Level 2

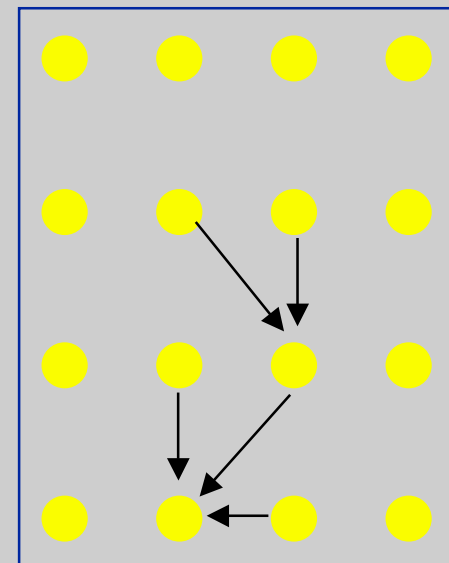
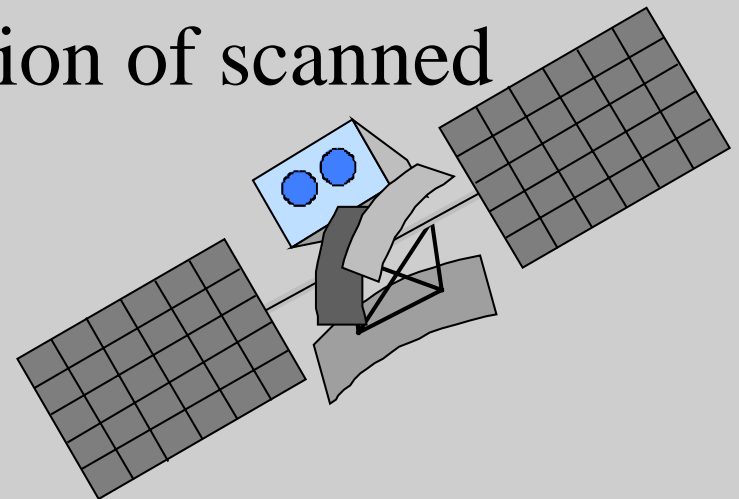


Image Processing

Analysis of raster images from scanners to interpret, display, and analyze map features.

Examples:

- Mapping of land cover using image data from the SPOT or Landsat satellite
- Display and manipulation of scanned facility drawings.



Document Management/Hypermedia

Storage and retrieval of geographically referenced documents (often optically scanned) in geographic query and analysis.

Examples:

- ✘ Use of GIS as pointer to scanned engineering drawings, site photographs, building permit forms, or deeds

