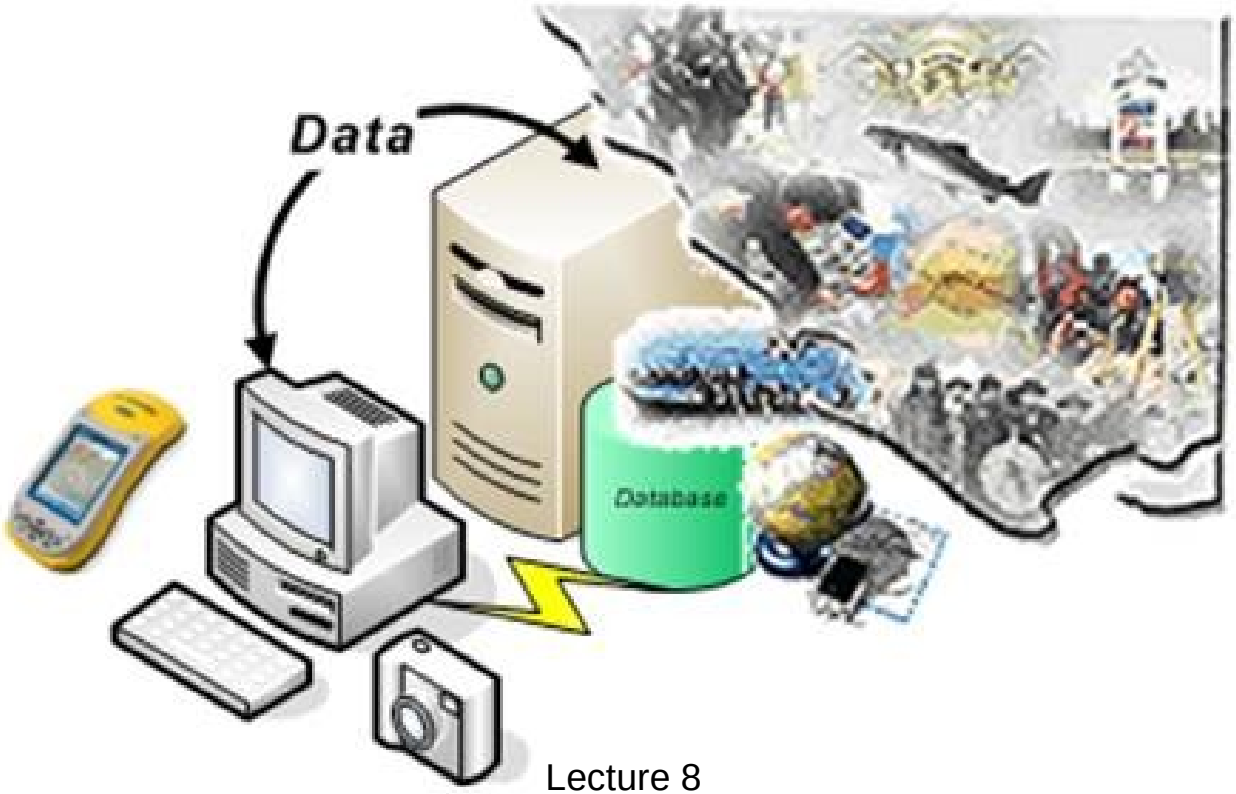
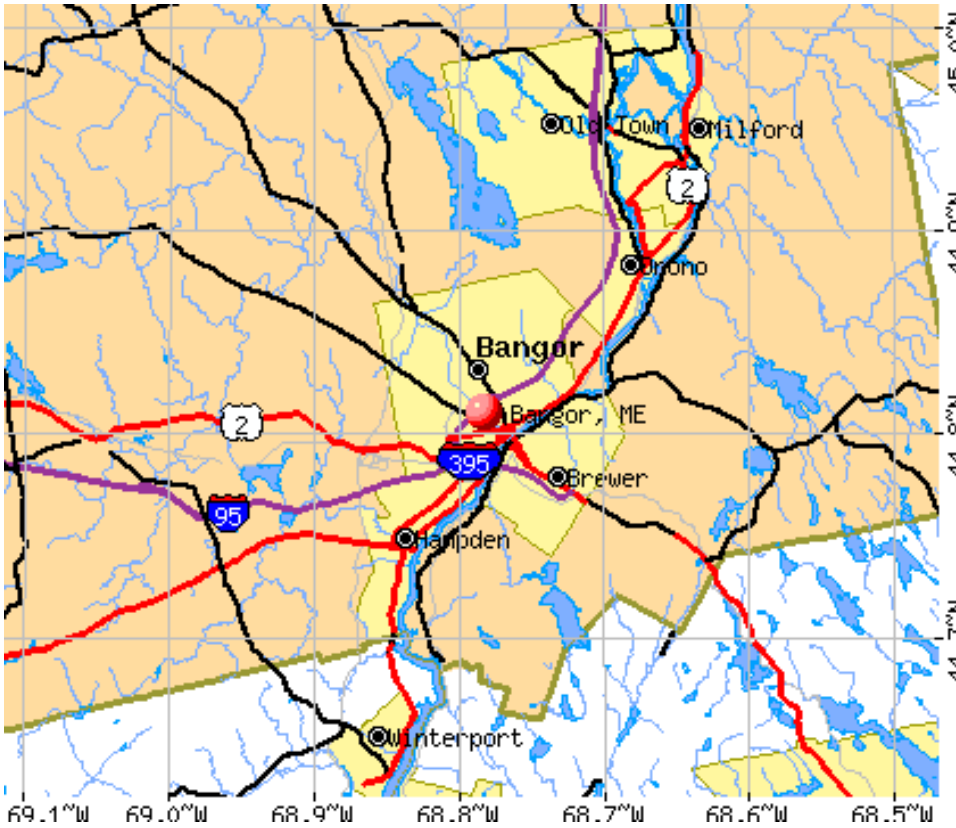
The GIS Database



Entity

Bangor

- Penobscot County, Maine, United States
- Centroid - 44.801N , -6778W
- Area 34.4 square miles
- Elevation – 158 feet
- Population 31,473



What is a database?

A database is any organized collection of data. Some examples common examples:

- a telephone book
- T.V. Guide
- airline reservation system
- motor vehicle registration records
- papers in your filing cabinet
- files on your computer hard drive.

Database Definitions

What is a database?

It's an organized collection of data, it need not be a computer based system.

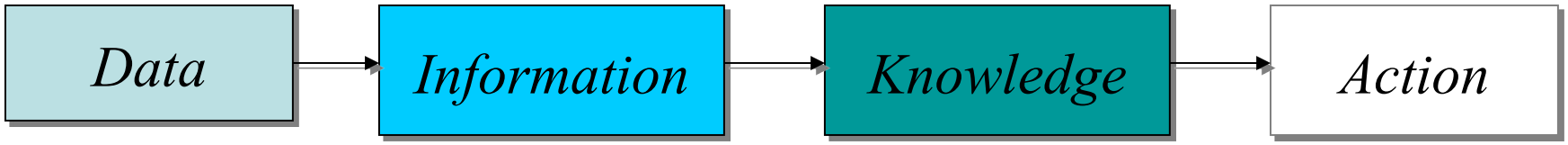
What is a database management system (DBMS)?

A software system designed to:

- Organize that data in a flexible manner,
- Provide tools to add, modify or delete data from the database,
- Query the data,
- Produce reports summarizing selected contents.

What is the ultimate purpose of a database management system?

Is to transform



Features of a DBMS

Database Management Systems provide features to maintain database:

- Data independence - It refers to the immunity of user applications to make changes in the definition and organization of data.
- Integrity and security - refers to maintaining and assuring the accuracy and consistency of data over its entire life-cycle

Features of a DBMS

Database Management Systems provide features to maintain database:

- Transaction management - A **transaction** comprises a unit of work performed within a DBMS against a database, and treated in a coherent and reliable way independent of other transactions. Transactions in a database environment have two main purposes:
  - To provide isolation from other transactions.
  - To have an “all or nothing” effect.

  Transactions must pass the ACID test (atomic, consistent, isolated and durable

Features of a DBMS

Database Management Systems provide features to maintain database:

- Concurrency control - ensures that correct results for concurrent operations are generated, while getting those results as quickly as possible.
- Backup and recovery
- Provides a language for the creation and querying of the database.
- A language for writing application programs

Selecting a Database Management System

Database management systems (or DBMSs) can be divided into two categories:

- Desktop databases are oriented toward single-user applications and reside on standard personal computers (hence the term desktop).
- Server databases contain mechanisms to ensure the reliability and consistency of data and are geared toward multi-user applications.

Relational Databases

- The relational database model is the most dominant model in both the corporate and GIS world, due to its flexibility, organization, and functioning..
- It was defined by Edgar F. Codd (1970).
- It can accommodate a wide range of data types.
- It is not necessary to know beforehand the types of processing that will be performed on the database.

Relational Database Terminology

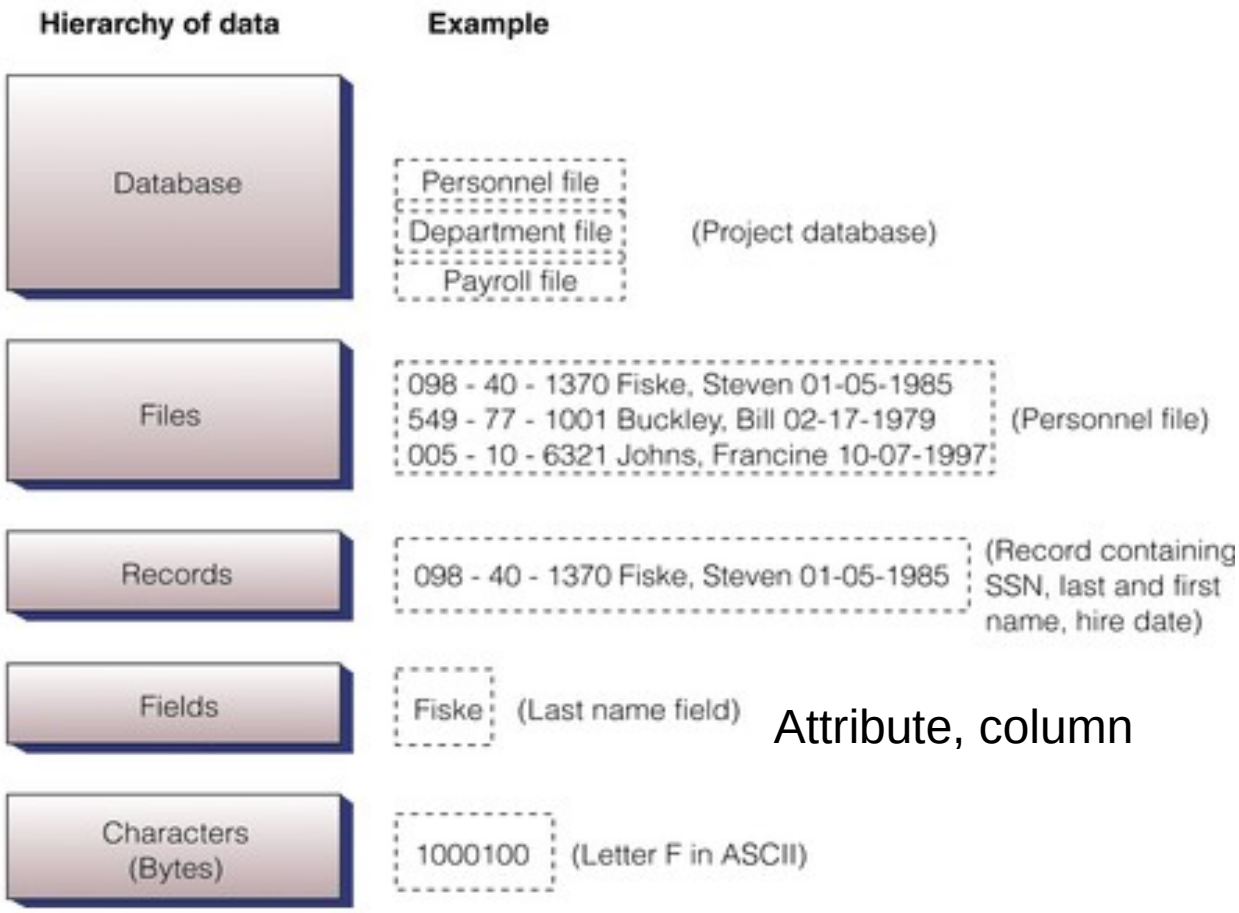
- Each table contains the data for a single entity.
- Each instance of an entity is a row/record/tuple in the table. This is a specific instance of the entity.
- Columns contain attributes/fields that describe the entity.
  - Attributes in a column must be from the same domain (text, integer, date).
  - An attribute may have a range (e.g.; $0 \leq \text{integers} \leq 100$)
  - Column order has no significance.
- Tables are related through keys.

Attributes

- An entity is represented by a set of attributes, that is descriptive properties possessed by all members of an entity set.

  Domain – the set of permitted values for each attribute
- Attribute types:
  - *Simple* and *composite* attributes.
  - *Single-valued* and *multi-valued* attributes
    - E.g. multivalued attribute: *phone-numbers*
  - *Derived* attributes
    - Can be computed from other attributes
    - E.g. *age*, given date of birth

Relational Database Terminology



Entity

Record, row, tuple
A specific instance of the entity

Attribute, column

Keys

- A *super key* of an entity set is a set of one or more attributes whose values uniquely determine each entity.
- A *candidate key* of an entity set is a minimal super key
  - *Customer-id* is candidate key of *customer*
  - *account-number* is candidate key of *account*
- Although several candidate keys may exist, one of the candidate keys is selected to be the *primary key*.

Super Key

MyTable					
ID	RollNumber	RegNo	Name	Place	Standard
1	12	1001	Amal	Trivandrum	12
2	13	1002	Ajith	Trivandrum	12
3	14	1003	Vijith	Trivandrum	12
4	15	1004	Shreya Sharma	Lucknow	12
5	16	1005	Shubham Sharma	Lucknow	12

ID, RollNumber, RegNo, Name, Place, Standard
ID, RegNo, Name
RegNo, Name, Place, Standard
RollNunmber, Name Place
ID, Place
RegNo

Candidate Keys

MyTable					
ID	RollNumber	RegNo	Name	Place	Standard
1	12	1001	Amal	Trivandrum	12
2	13	1002	Ajith	Trivandrum	12
3	14	1003	Vijith	Trivandrum	12
4	15	1004	Shreya Sharma	Lucknow	12
5	16	1005	Shubham Sharma	Lucknow	12

ID
RollNumber
RegNo

Primary Key

MyTable					
ID	RollNumber	RegNo	Name	Place	Standard
1	12	1001	Amal	Trivandrum	12
2	13	1002	Ajith	Trivandrum	12
3	14	1003	Vijith	Trivandrum	12
4	15	1004	Shreya Sharma	Lucknow	12
5	16	1005	Shubham Sharma	Lucknow	12

ID

Keys

- A *composite key/concatenated* is a key with more than one attribute.

WORK

Employee ID	Project ID	Hours_Worked
01	01	200
01	02	120
02	01	50
02	03	120
03	03	100
03	04	200

http://ecomputernotes.com/images/Composite%20Key.jpg

Keys

- A *foreign key* is an attribute that is a key of one or more relations other than the one in which it appears.

Foreign Key

Data table 1: Project table

Primary Key

Project number	Description	Dept. number
155	Payroll	257
498	Widgets	632
226	Sales Manual	598

Foreign Key

Data table 2: Department table

Primary Key

Dept. number	Dept. name	Manager SSN
257	Accounting	005-10-6321
632	Manufacturing	549-77-1001
598	Marketing	098-40-1370

Foreign Key

Data table 3: Manager table

Primary Key

SSN	Last name	First name	Hire date	Dept. number
005-10-6321	Johns	Francine	10-07-1997	257
549-77-1001	Buckley	Bill	02-17-1979	632
098-40-1370	Fiske	Steven	01-05-1985	598

Foreign Key

Keys

- Given the importance of keys, there are usually some restrictions on them: e.g., null values are not allowed.
- Keys are also used to index a database.
  - Too few keys may result in difficulty in searching and sorting the database.

Physical Database Structure

The physical design of the database specifies the physical configuration of the database on the storage media.

- This includes detailed specification of data elements, data types, indexing options and other parameters residing in the DBMS data dictionary.
- It is the detailed design of a system that includes modules & the database's hardware & software specifications of the system.

https://en.wikipedia.org/wiki/Database_design

Logical Database Structure

- Several logical data structures are used to express the relationships between individual data elements or records in a database.
- Common logical data structures are hierarchical, network, and relational, with relational being predominant.

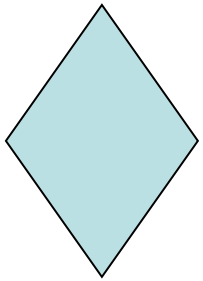
Conceptual Structure

- The conceptual structure is often represented as a schema.
- A schema describes the database structure in a shorthand notation.
- One example is the entity-relationship (ER) diagram.

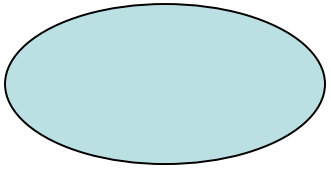
Entity Relationship Diagram

ENTITY

RELATIONSHIP

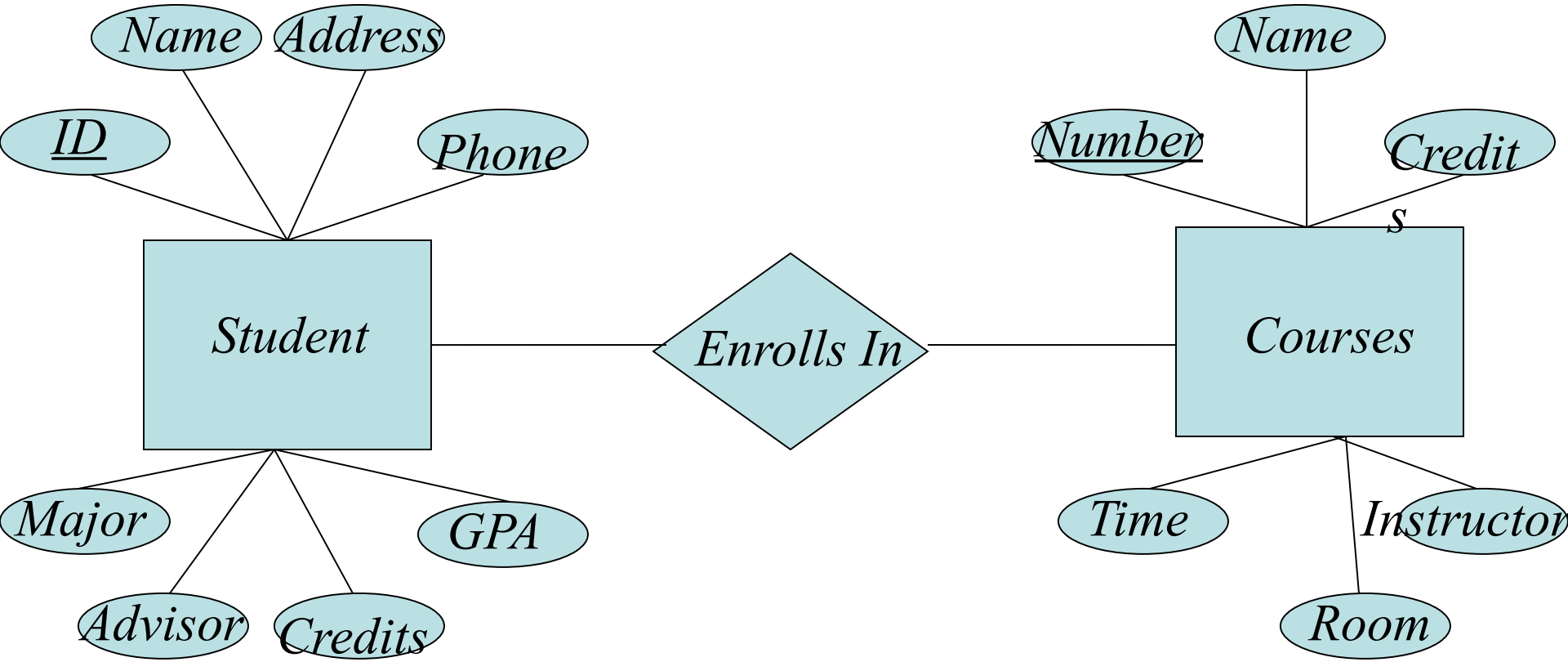


ATTRIBUTE



- **Rectangles** represent entity sets.
- **Diamonds** represent relationship sets.
- **Lines** link attributes to entity sets and entity sets to relationship sets.
- **Ellipses** represent attributes
  - **Double ellipses** represent multivalued attributes.
  - **Dashed ellipses** denote derived attributes.
- **Underline** indicates primary key attributes.

Entity Relationship Diagram



Types of Relationships between Entities

- 1:1 – one faculty member is assigned to one office.
- 1:M (M:1) – one faculty member teaches many courses.
- M:N – many students take many courses.
- All of these relationships can exist between **attribute tables**.

Table Join

Forests

Forest Name	Forest-ID	Location	Size
Nantahala	1	N. Carolina	184,447
Cherokee	2	N. Carolina	92,271

Trails

Trail Name	Forest-ID
Bryson's Knob	1
Slickrock Falls	2
North Fork	1
Cade's Cove	1
Cade's Cove	2
Appalachian	1
Appalachian	2

Table from Relational Join

Forest Name	Forest-ID	Location	Size	Trail Name
Nantahala	1	N. Carolina	184,447	Bryson's Knob
Nantahala	1	N. Carolina	184,447	North Fork
Nantahala	1	N. Carolina	184,447	Cade's Cove
Nantahala	1	N. Carolina	184,447	Appalachian
Cherokee	2	N. Carolina	92,271	Slickrock Falls
Cherokee	2	N. Carolina	92,271	Cade's Cove
Cherokee	2	N. Carolina	92,271	Appalachian

Table Joins

- Table joins depend on the **data** not the **attribute name**.
- There are many different types of table joins.
- Tables can be joined regardless of the relationship EXCEPT:
  - When joining to the feature attribute table in a GIS, the relationship must be 1:1 or M:1
  - Other relationships must use the relate.

One-to-One Join

Employee-id	Job
1	Digislave
2	Useless Supervisor

Employee-id	name
1	Tom
2	John

Join Employee-id to Employee-id

After join

Employee-id	Job	Name
1	Digislave	Tom
2	Useless Supervisor	John

A join does not permanently alter the table structure

Many-to-One Join

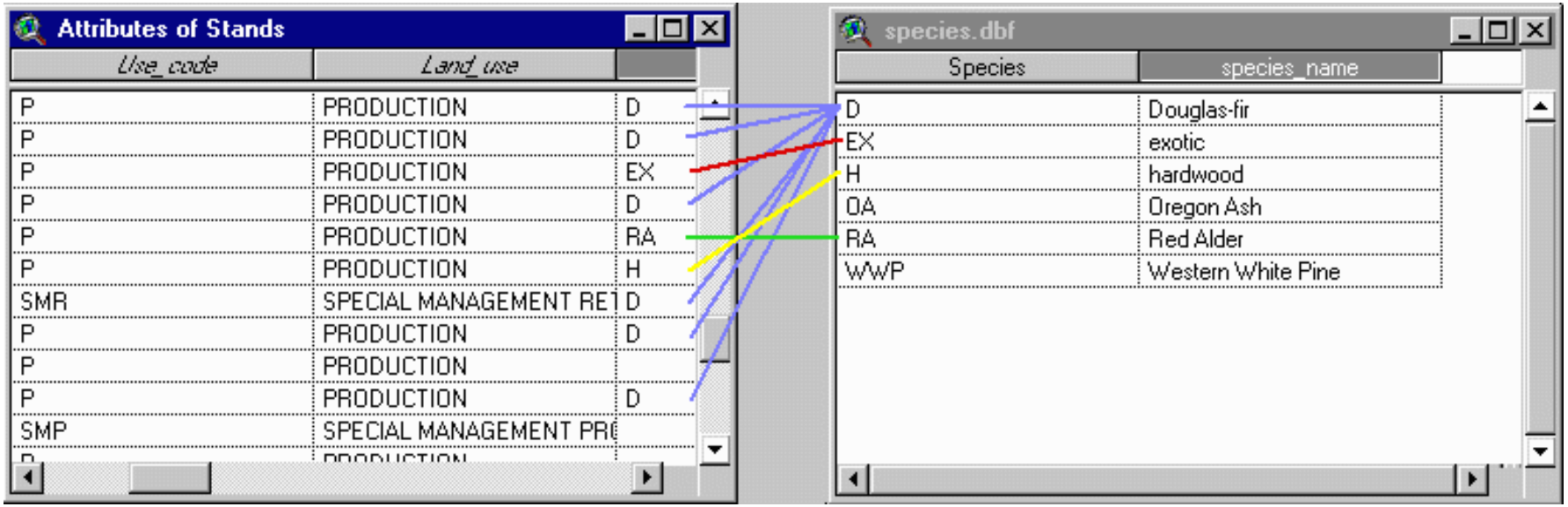
Polygon Id	Symbol
1	Qa
2	Qa
3	Pa
4	Qe

Symbol	Description
Qa	Quaternary Alluvium
Qe	Quaternary Eolian
Pa	Permian Abo

After Join on Symbol

Polygon ID	Symbol	Description
1	Qa	Quaternary Alluvium
2	Qa	Quaternary Alluvium
3	Pa	Permian Abo
4	Qe	Quaternary Eolian

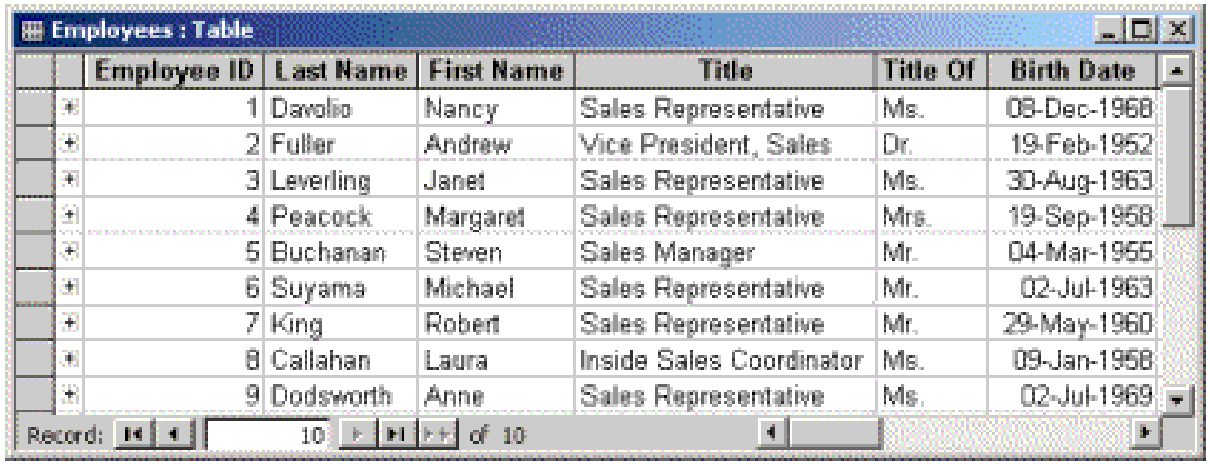
Relate in a GIS



https://courses.washington.edu/gis250/lessons/tables/images_av3/relate_table1.gif

Fundamental Building Blocks

Tables comprise the fundamental building blocks of any database.



Employees : Table

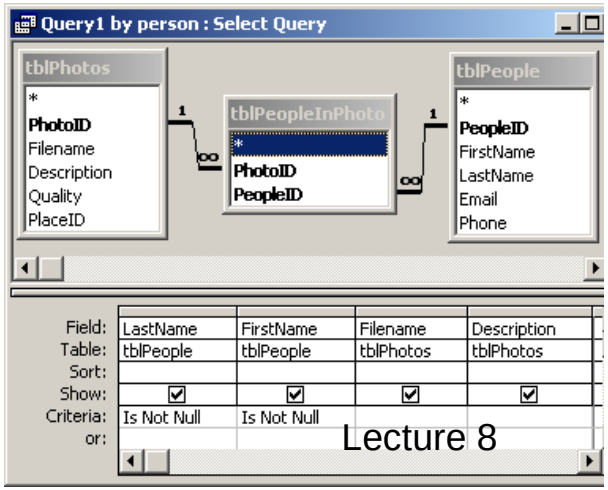
Employee ID	Last Name	First Name	Title	Title Of	Birth Date
1	Davolio	Nancy	Sales Representative	Ms.	08-Dec-1968
2	Fuller	Andrew	Vice President, Sales	Dr.	19-Feb-1952
3	Leverling	Janet	Sales Representative	Ms.	30-Aug-1963
4	Peacock	Margaret	Sales Representative	Mrs.	19-Sep-1958
5	Buchanan	Steven	Sales Manager	Mr.	04-Mar-1955
6	Suyama	Michael	Sales Representative	Mr.	02-Jul-1963
7	King	Robert	Sales Representative	Mr.	29-May-1960
8	Callahan	Laura	Inside Sales Coordinator	Ms.	09-Jan-1958
9	Dodsworth	Anne	Sales Representative	Ms.	02-Jul-1969

Record: 10 of 10

The table above contains the employee information for an organization -- characteristics like name, date of birth and title.

Database Queries

- Queries may be made of one table or several tables at the same time.
- In many systems querying is facilitated by icons, or menus, or queries by example (QBE – a graphical query language).



Structured Query Language (SQL)

- DDL – Data Definition Language; used to create and manage the database.
- DDM – Data Manipulation Language; used to query the database.

SQL

- SQL: widely used non-procedural language
  - E.g. find the name of the customer with customer-id 192-83-7465

    select *customer.customer-name*
    from *customer*
    where *customer.customer-id* = ‘192-83-7465’
- Application programs generally access databases through one of
  - Language extensions to allow embedded SQL
  - Application program interface (e.g. ODBC/JDBC) which allow SQL queries to be sent to a database

Attribute Queries

Simple selection:

records with Area > 20.0

ID	Area	Landuse	Municip
1	10.5	Urban	City
2	330.3	Farm	County
3	2.4	Suburban	Township
4	96.0	Suburban	County
5	22.1	Urban	City
6	30.2	Farm	Township
7	4.4	Urban	County

AND selection:

records with (Landuse = Urban) **and** (Municip = City)

ID	Area	Landuse	Municip
1	10.5	Urban	City
2	330.3	Farm	County
3	2.4	Suburban	Township
4	96.0	Suburban	County
5	22.1	Urban	City
6	30.2	Farm	Township
7	4.4	Urban	County

OR selection:

records with (Area > 20.0)
OR (Municip = City)

ID	Area	Landuse	Municip
1	10.5	Urban	City
2	330.3	Farm	County
3	2.4	Suburban	Township
4	96.0	Suburban	County
5	22.1	Urban	City
6	30.2	Farm	Township
7	4.4	Urban	County

NOT selection:

records with
Landuse NOT Urban

ID	Area	Landuse	Municip
1	10.5	Urban	City
2	330.3	Farm	County
3	2.4	Suburban	Township
4	96.0	Suburban	County
5	22.1	Urban	City
6	30.2	Farm	Township
7	4.4	Urban	County

NOT [(Landuse = Urban) AND (Municip = County)]

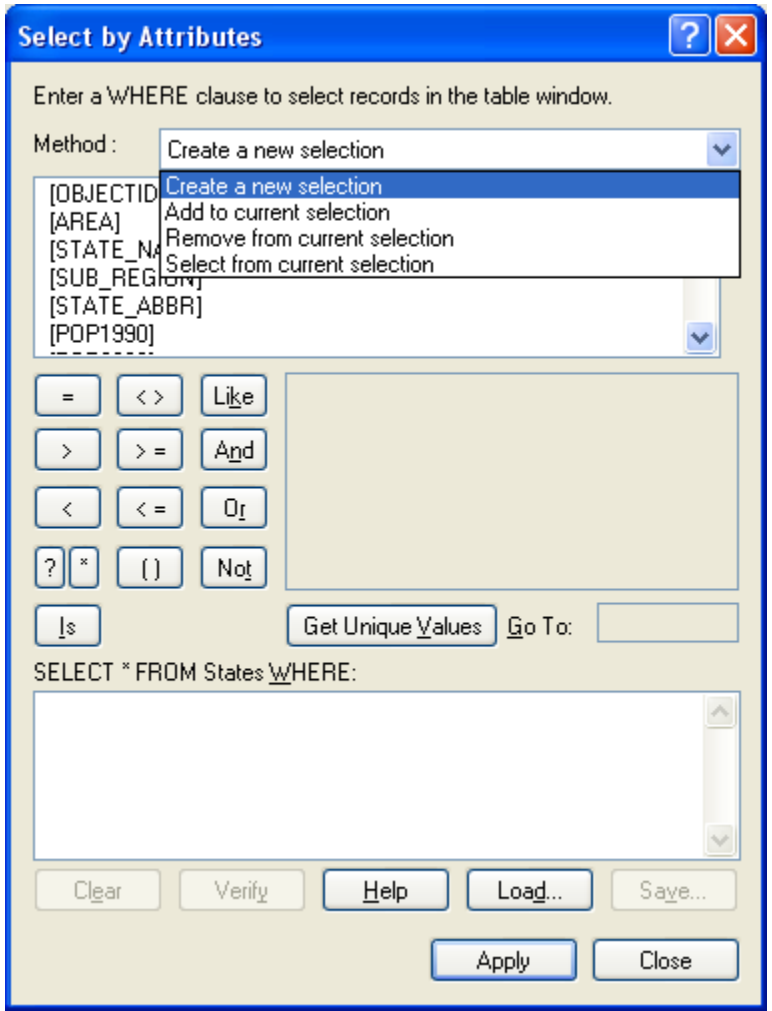
ID	Area	Landuse	Municip
1	10.5	Urban	City
2	330.3	Farm	County
3	2.4	Suburban	Township
4	96.0	Suburban	County
5	22.1	Urban	City
6	30.2	Farm	Township
7	4.4	Urban	County

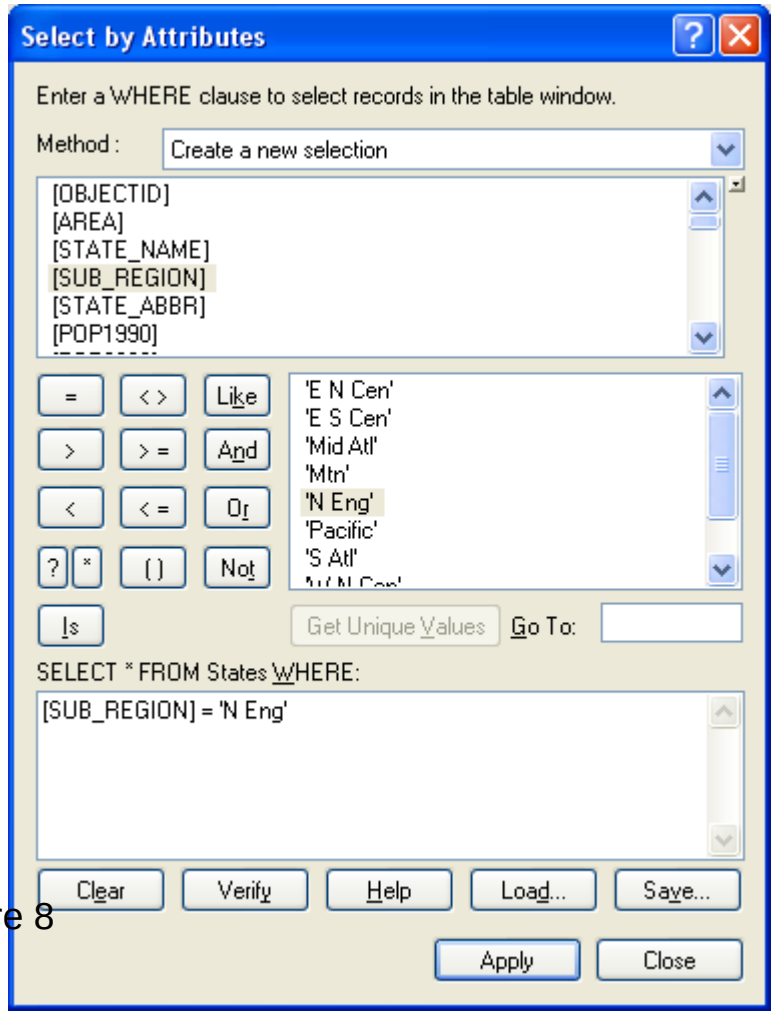
[NOT (Landuse = Urban)] AND [NOT (Municip = County)]

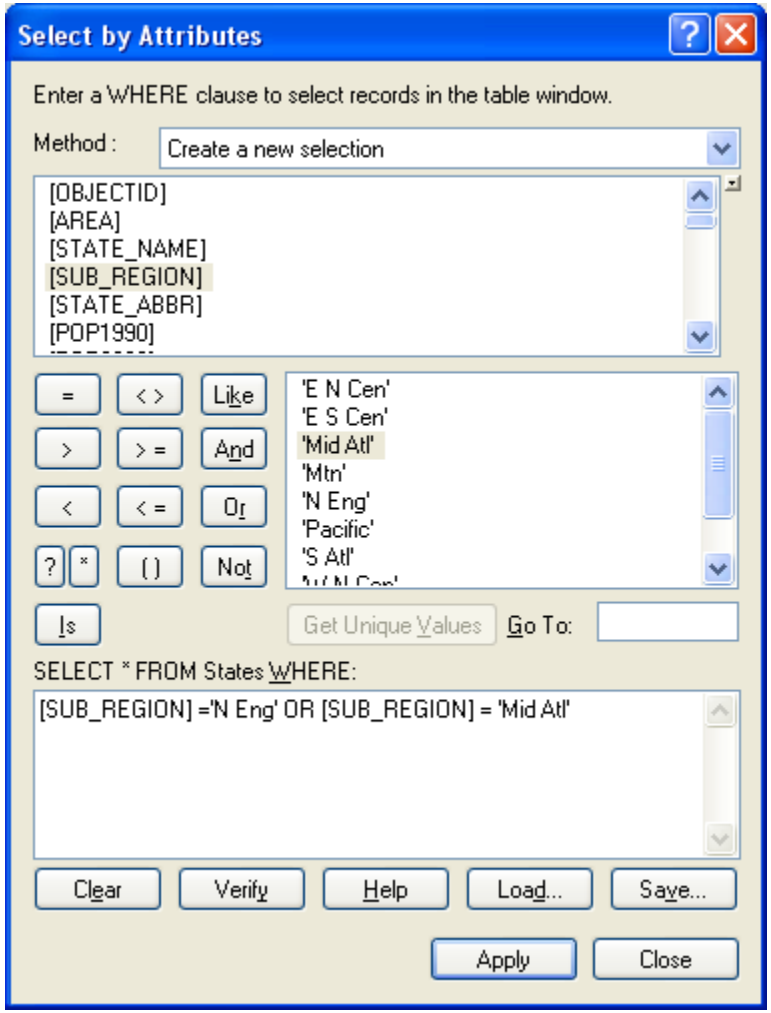
ID	Area	Landuse	Municip
1	10.5	Urban	City
2	330.3	Farm	County
3	2.4	Suburban	Township
4	96.0	Suburban	County
5	22.1	Urban	City
6	30.2	Farm	Township
7	4.4	Urban	County

The ArcGIS Attribute Query Interface

State's Table is Open






Select by Attributes
Enter a WHERE clause to select records in the table window.
Method :
Create a new selection
[OBJECTID]
[AREA]
[STATE_NAME]
[SUB_REGION]
[STATE_ABBR]
[POP1990]
= < > Like
> > = And
< < = Or
? * ( ) Not
'E N Cen'
'E S Cen'
'Mid Atl'
'Mtn'
'N Eng'
'Pacific'
'S Atl'
Is
Get Unique Values
Go To:
SELECT * FROM States WHERE:
[SUB_REGION] ='N Eng' OR [SUB_REGION] = 'Mid Atl'
Clear
Verify
Help
Load...
Save...
Apply
Close

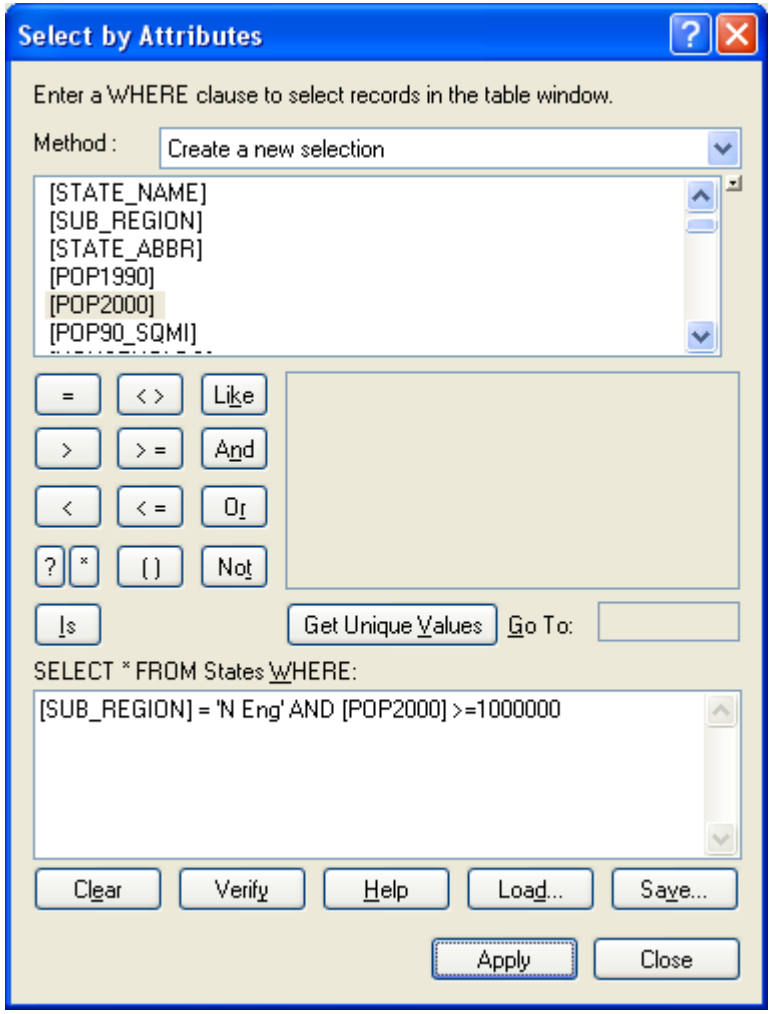
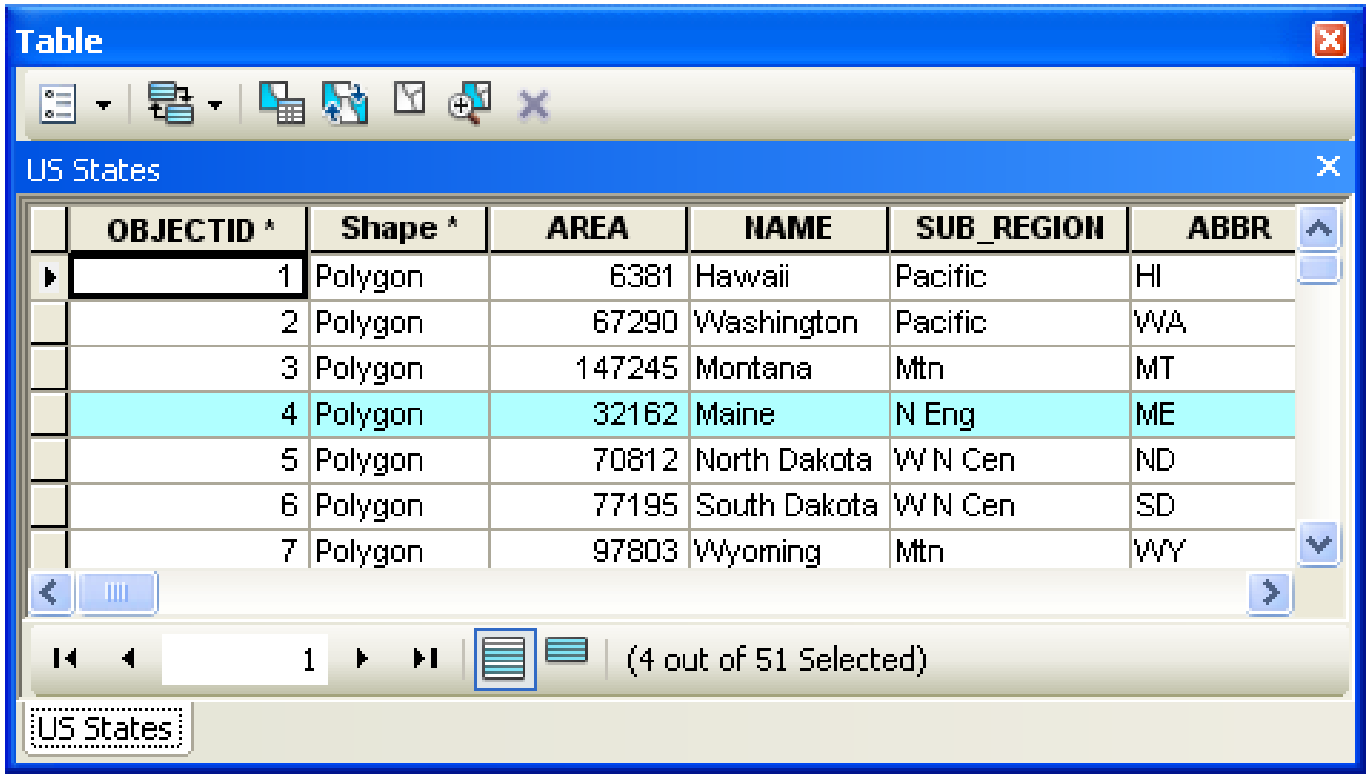
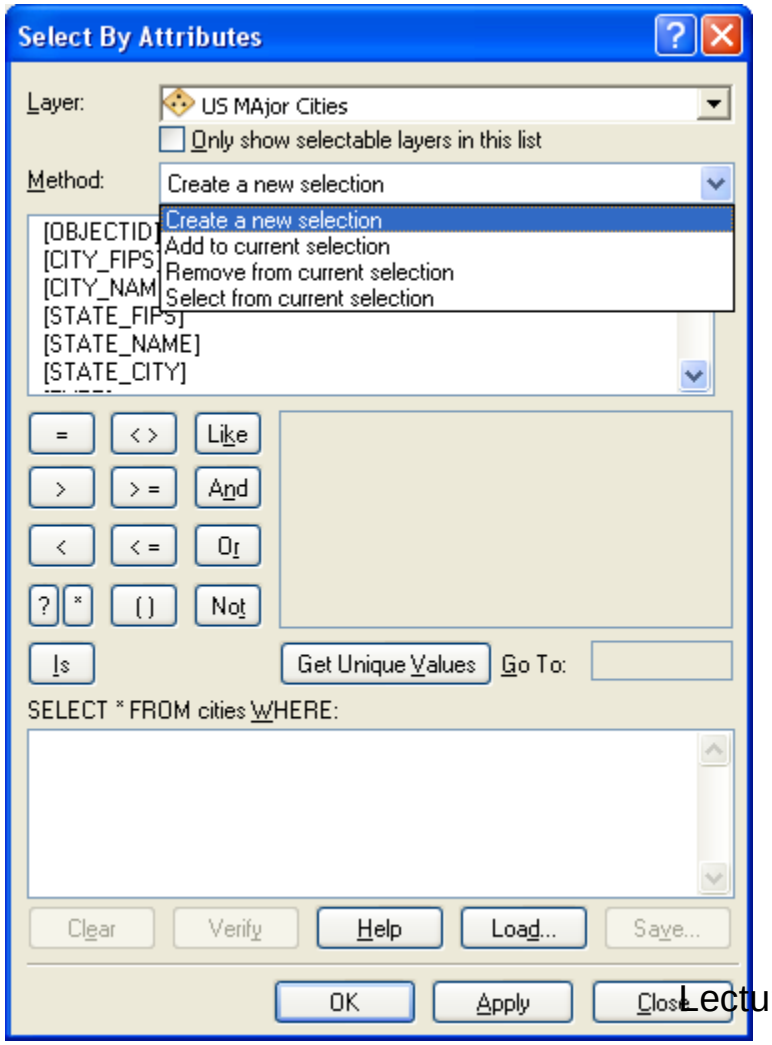

Select by Attributes
Enter a WHERE clause to select records in the table window.
Method :
Create a new selection
[STATE_NAME]
[SUB_REGION]
[STATE_ABBR]
[POP1990]
[POP2000]
[POP90_SQMI]
= < > Like
> > = And
< < = Or
? * ( ) Not
Is
Get Unique Values
Go To:
SELECT * FROM States WHERE:
[SUB_REGION] = 'N Eng' AND [POP2000] >=1000000
Clear
Verify
Help
Load...
Save...
Apply
Close

Table is Open



Options
Related tables
Select by attributes
Switch selection
Clear selection
Zoom to selected
Delete Selected

No Table is Open

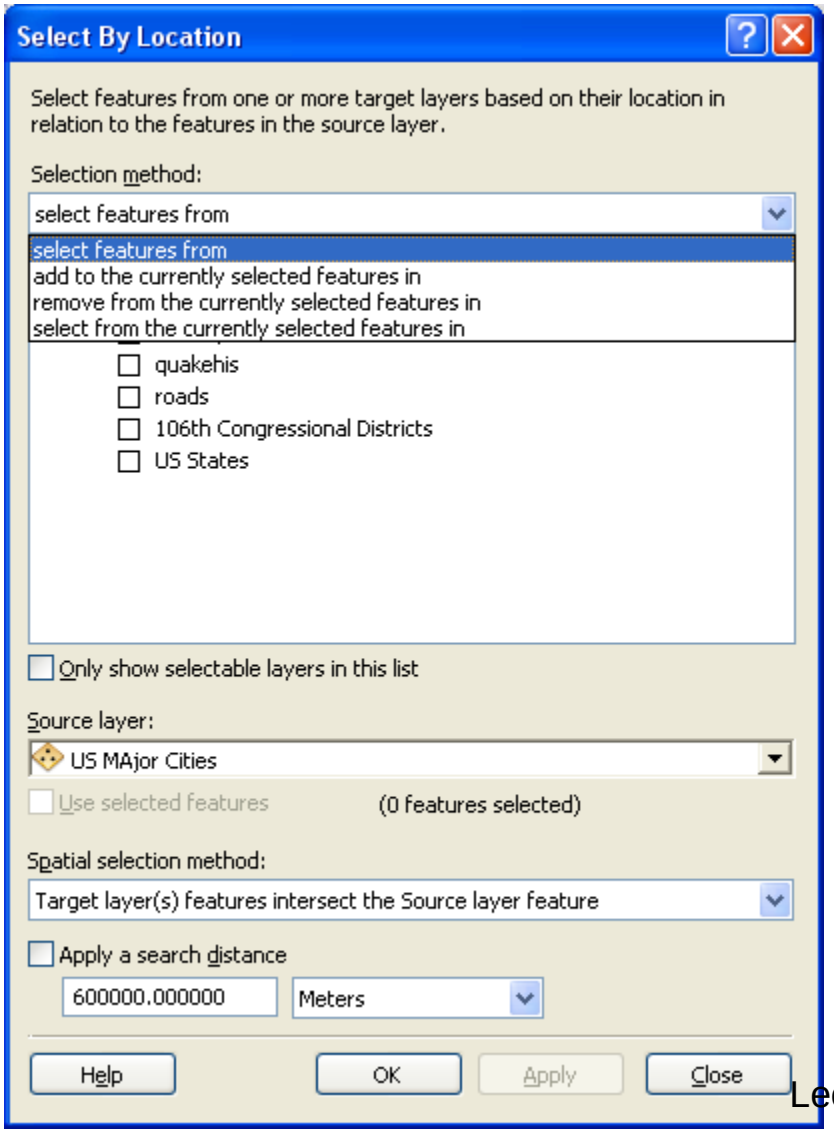


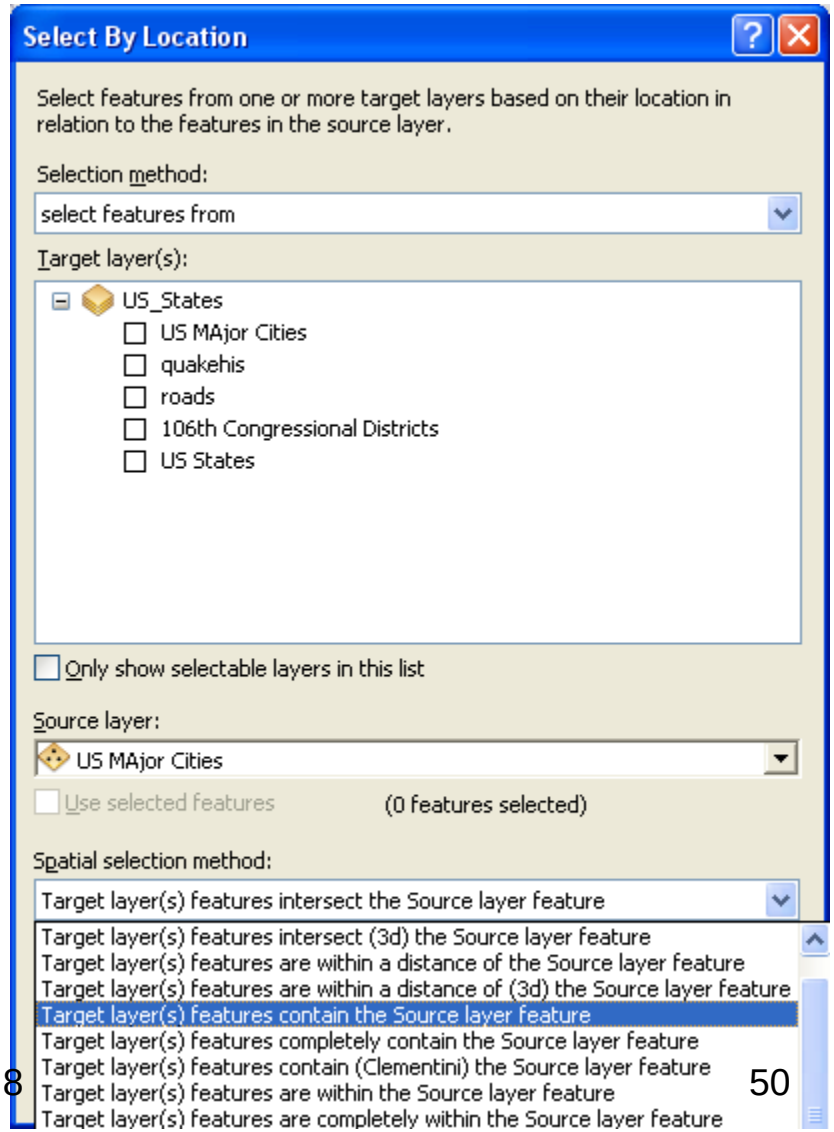
Selection->Select by Attributes from the Menu Bar

A Spatial Query in SQL

```
SELECT city.name, city.geometry
FROM    city, county
WHERE county.name='Penobscot' AND
        city.geometry INSIDE county.geometry
        city.population>30000;
```

Spatial Selection

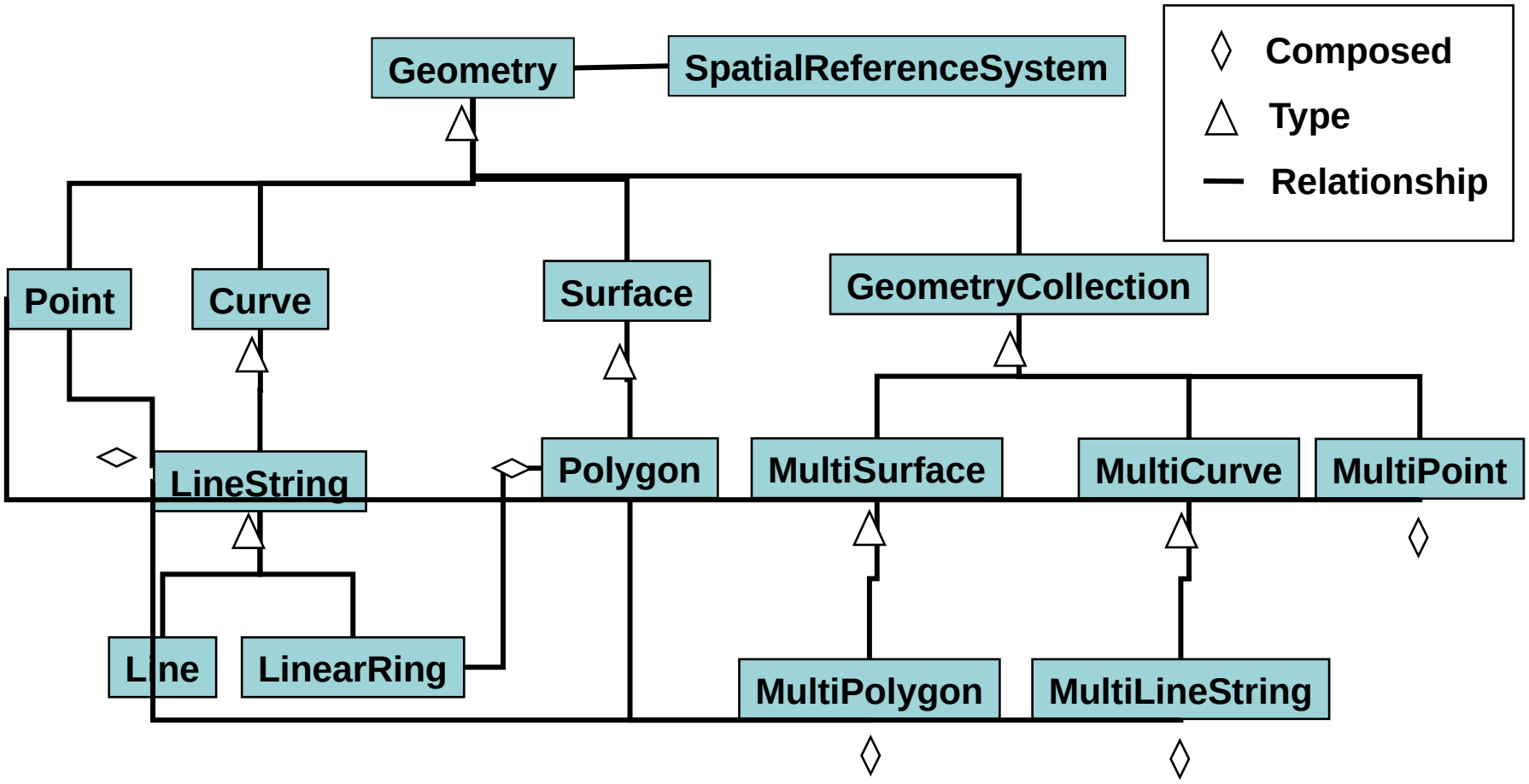




Spatial Data

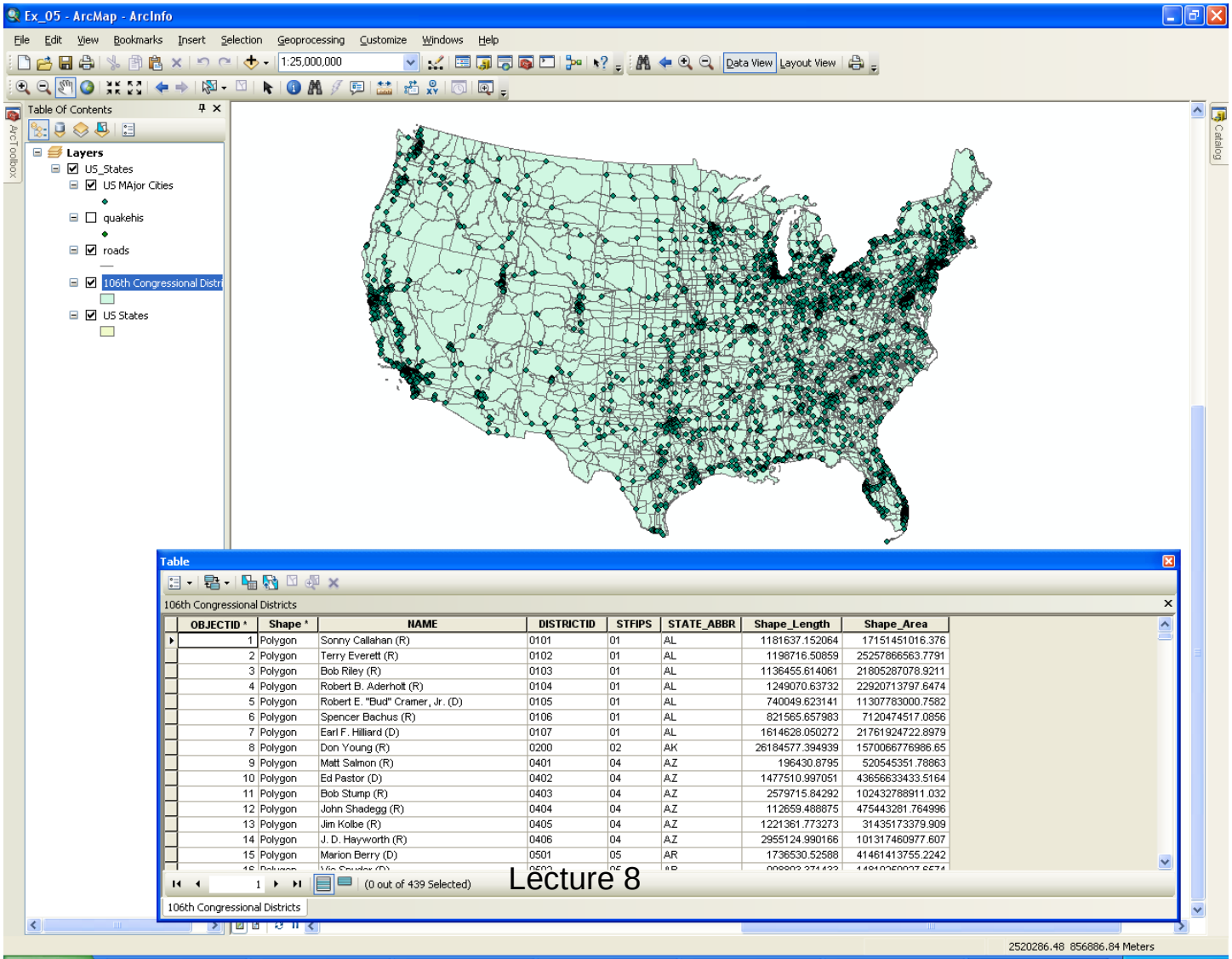
- Spatial data has a structure that does not necessarily fit with tabular structure.
- To construct a spatial object requires several table joins.
- Spatial indexing is very different from the type of indexing used in a relational database.

Spatial Types – OGC Simple Features

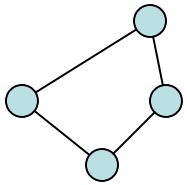


Standard GIS Data Model

Linked spatial and attribute (tabular) data.

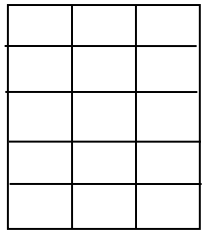


File-based Data Models



Arc

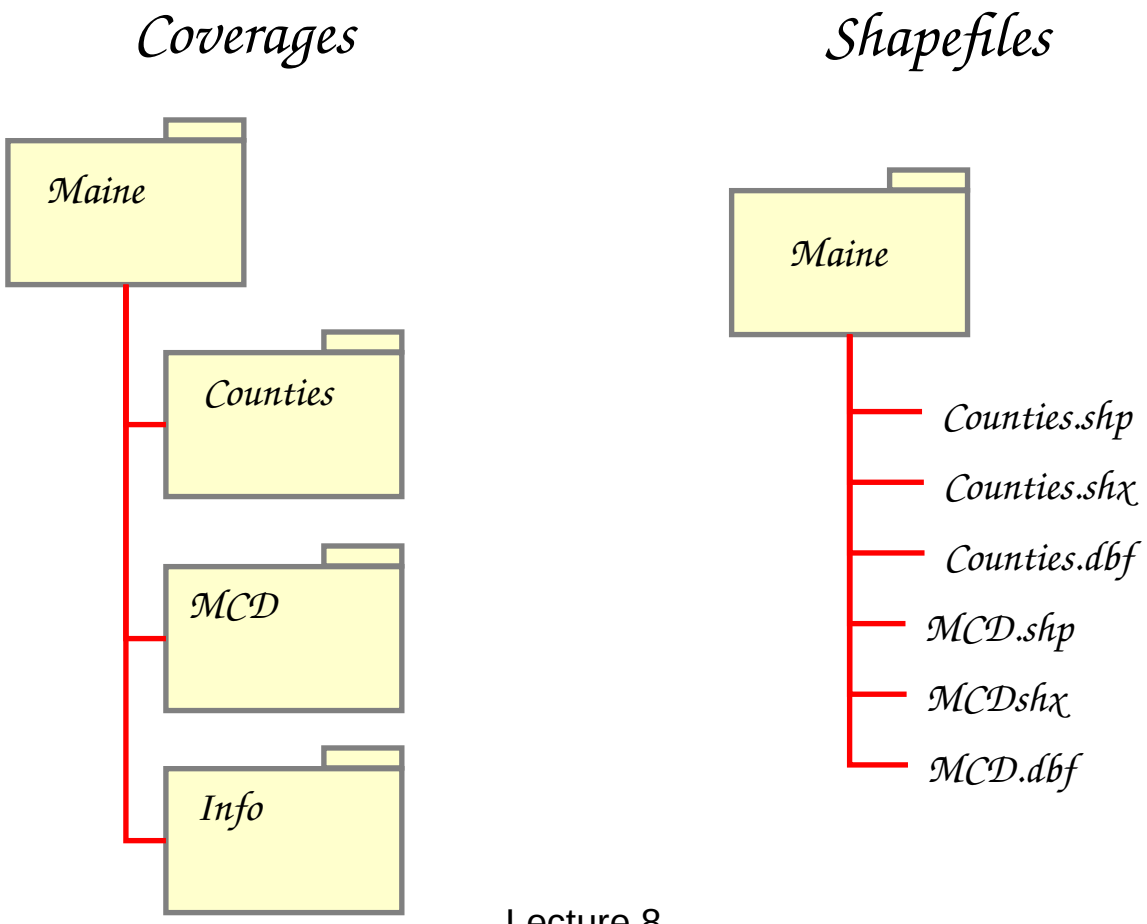
Geographic coordinates and attributes are stored in separate but linked files



Info

- Coverages
  - Developed for workstation Arc/Info ~ 1980
  - Complex structure, proprietary format
  - Attributes in Info tables
- Shapefiles
  - Developed for ArcView ~ 1993
  - Simpler structure in public domain
  - Attributes in dBase (.dbf) tables

Storing Data



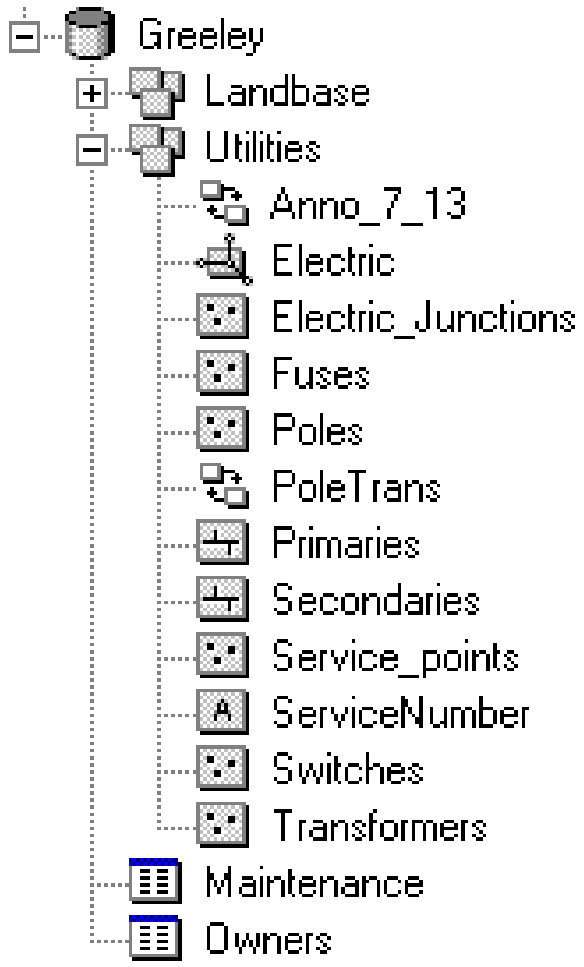
Coverages and Shapefiles

- Coverages are stored partially in their own folder and partially in the common INFO folder.
- Shapefiles are stored in three to five files (with extensions .shp, .shx, .dbf, .sbx and .sbn).
- Coverages store common boundaries between polygons only once, to avoid redundancy.
- Shapefiles store all the geometry of each polygon regardless of redundancy.
- Coverage features are single lines or single polygons.
- Shapefiles allow features to have multiple, disconnected, intersecting and overlapping components.

Geodatabase Model

- Stores geographic coordinates as one attribute (shape) in a relational database table
- Uses MS Access for “Personal Geodatabase” (single user)
- Uses a file system for a “File Geodatabse” (FGDB).
- Uses Oracle, Sybase, Ingress or other commercial relational databases for “Enterprise Geodatabases” (many simultaneous users)

Elements of a Geodatabase



Geometric Network

Feature Dataset

Relationship Class

Feature Class

Annotation Class

Object Class

Elements of a Geodatabase

- Objects , Object Classes
- Features , Feature Classes
- Feature Datasets
- Validation Rules, Domains
- Relationships , Relationship Classes
- Spatial References
- Geometric Networks

Objects and Object Classes

- An object is an instance of an object class
- All objects in an object class have the same properties and behavior
- An object can be related to other objects via relationships

Object view	Relational view
Attribute	Column, Field
Object	Row
Object class	Table
Feature	Row with geometry column
Feature class	Table with geometry column
Relationship	Row with two foreign keys
Relationship class	Table with two foreign key columns
Network	Tables linking elements to features

Features

- Spatial object
- Location
  - Attribute of type *Geometry*
- Spatial relationships
- Instance of a feature class

Feature Classes

- Same type of geometry
- Same type of spatial reference system
- Store spatial objects (features)

Feature Datasets

- Container
- Same spatial reference
- Analogous to a coverage