



Creating Compatible CAD Data for ArcGIS® Software

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Creating Compatible CAD Data for ArcGIS Software

Purpose The purpose of this technical document is to provide Computer-Aided Drafting (CAD) and/or geographic information system (GIS) managers with guidelines for building CAD data that is easily used as GIS content. If you are a CAD professional and are unsure what a GIS professional is looking for in your drawings, this document will help you. If you are a GIS professional and are unsure what to ask for from those providing data in CAD format, this document should help you.

Clearly the best way to create GIS data is by using a GIS editor; however, you may not always have control over the applications used to generate GIS data. This document is designed to assist those who must use CAD to build GIS content or who rely on others who use CAD as a source of data. This technical paper is not intended to suggest that GIS should be used instead of CAD or even to recommend how to create CAD drawings, but rather is written to inform you which CAD data construction methods are most usable by ArcGIS® Desktop (ArcView®, ArcEditor™, and ArcInfo™). With this information you can make more informed decisions.

By avoiding some CAD data construction methods that can degrade the quality of CAD data for use in the GIS and following a few simple strategies for data construction and organization, you can build CAD data that works well within ArcGIS Desktop. It is acknowledged, however, that the optimum methods for constructing a CAD drawing for its primary purpose may include data objects and CAD modeling techniques that are troublesome for GIS to use effectively. Simply knowing what these issues are can assist those working in both worlds to avoid certain methods and use alternate ones that can improve interoperability. Even when the data may not be intended for GIS use, you can still make some simple data construction choices that improve any future GIS use of CAD drawings.

Introduction

CAD Data as GIS Content

CAD files can contain a wealth of GIS content. There are various ways to access that GIS content using ArcGIS. ArcGIS can read CAD files "as is," convert the CAD file data into a GIS format, or translate the CAD data using various rule-based processes. ArcGIS provides tools to access CAD information using each of these techniques depending on the needs of the GIS application and the content and configuration of the data within the CAD file.

Often CAD data can be useful in a GIS context simply by viewing it together with other GIS data. In that respect, ArcGIS can view a CAD file as an ArcGIS CAD drawing data set, which is manipulated in ArcGIS as a single GIS data layer. The vector-based CAD

drawing data set is a representation of the CAD file that is handled similarly to the way a raster image is used as an overlay or to give a background context for other data within ArcGIS.

CAD files can also be viewed by ArcGIS as a source of GIS geographic features. ArcGIS interprets a CAD file as a collection of GIS feature classes using its native CAD file reading capability. The ArcGIS CAD feature data sets are derived directly from a CAD file without the need for conversion or translation by simply opening the file in ArcGIS.

The Flexibility of CAD Data Construction

In CAD, you have the ability to draw a line similar to using a pencil on a piece of paper. The intended meaning of that line may be a road or sewer pipe, or it might be used as part of a graphic detail to highlight something on a map. The point is that CAD can be used to represent and model sophisticated data systems or simple sketches and pictures. The actual meaning of the lines that are drawn are inferred from the context of the overall work product or coded into arbitrary standards of CAD symbology, such as a CAD layer or color, or by varying an object's graphic symbology. CAD files are unconstrained when it comes to data creation, and meaning is inferred by context or recognized through the adoption of voluntary CAD standards. In ArcGIS the meaning of data is described in a database context with a predefined geometric representation, optional topological business rules, and a tabular database schema. In ArcGIS there is no ambiguity as to the identity of objects or their inclusion or exclusion within a system of geographic features. The same cannot be said about CAD data unless the user or a controlling application is maintaining CAD standards.

The free-form nature of CAD makes for a powerful and unconstrained drafting environment. It is easy to construct geometric representations of almost anything in any number of ways. It is this free-form editing environment that can lead to problems when attempting to fit the graphic and geometric free-form abstractions of real-world features into the organized data structures commonly found in ArcGIS. CAD data can be drawn in such a way that it mimics the data structures and organization of GIS, or it can be a jumble of inconsistent data constructs and loosely enforced CAD standards that looks exactly the same as the well-organized GIS map when printed on paper.

Improving CAD Data's Usefulness as GIS Content

GIS professionals who want to make use of CAD data seldom have authority when it comes to dictating the format, data structure, or content of CAD work products. The reason is that they do not usually pay for their creation nor are they responsible for the usefulness of the products for their primary purpose: engineering design and construction. The usability of CAD drawings as GIS content, however, can be greatly improved with minimal effort during the CAD drafting process.

When GIS professionals are at liberty to dictate or at least contribute to how CAD data is to be constructed, using the guidelines in this document should be strongly considered and then enforced as part of your organization's CAD standard. Anything that can be done to uniquely identify unique objects and avoid ambiguity is key to successful reuse of CAD data as GIS content. Being able to uniquely identify and distinguish between objects in a systematic way will always make CAD data more usable as GIS content. The goal is not to substitute CAD for a GIS editor or force CAD professionals to adopt

the data modeling techniques of GIS but rather to simply recommend one CAD technique over another that will improve the usefulness of the CAD files as GIS content.

In the process of designing and building real-world assets, engineers and designers make little or no use of GIS technology. However, the results of their efforts may have high value as GIS content. To leverage the original design effort, a few simple steps by the CAD operator during the original design effort can save a significant amount of work for the data consumer. When the CAD data creators and the GIS data consumers work together, there can be a significant cost savings in data management and an improvement in overall data quality.

Understanding the Spatial Reference for CAD Files

It is sometimes said that CAD and GIS are in different worlds. However, when integrating or interoperating between CAD and GIS, we are reminded that we do share the same globe, namely earth. CAD files store geometry in a Cartesian coordinate system using x,y,z coordinate values to represent the position of objects in a design space. ArcGIS also stores x,y,z coordinates when representing objects in a mapping space. In CAD it is not required that you define the context of the design space within which you are working. ArcGIS also does not require that data be identified as belonging to a defined mapping space. However, when data is added to an ArcGIS mapping frame, all data will fit relative to each data set's spatial reference. If a data set does not have a defined spatial reference, the coordinates will be assumed to be the current map frame's coordinate system. That may or may not be correct for data having an undefined spatial reference; therefore, it is strongly advised that you identify the actual coordinate space of all GIS data including CAD data.

Projections are necessary to accurately portray geospatial information on a spherical globe within the design cube of the Cartesian coordinate system. Because it is often impractical to encode geospatial features, much less CAD data, using geographic or spherical coordinate systems, it is standard practice to use a Cartesian coordinate system with a defined or assumed projected coordinate system.

Often CAD data may be measured and recorded using a mapping coordinate system such as State Plane, Universal Transverse Mercator (UTM), or some other named projection. Although data sets may have been recorded and drafted according to a known coordinate system, ArcGIS must be made aware of which coordinate system is being used. This is accomplished by defining an ArcGIS spatial reference. Using ArcGIS, you can easily define, or select from an exhaustive list, the spatial references for a CAD file. The spatial reference defined or selected for a CAD file can be stored in a special ArcGIS projection file. When this projection file accompanies a CAD file, it is automatically read by ArcGIS to identify the spatial reference. If the spatial reference of the ArcGIS map frame is different from the spatial reference of the CAD data, the CAD data can be automatically projected on the fly because its spatial reference has been made known to ArcGIS.

What if the CAD data has been created using a local arbitrary coordinate system or is in page units? CAD data that has been drafted without a geospatial context can still be usable in ArcGIS. To be made usable, the CAD data must first be tied into a known coordinate system either by actually moving, rotating, and scaling the data within CAD

or by creating an ArcGIS world file. The world file is a special file used by ArcGIS that stores the information needed to move, scale, and rotate a CAD file into a known coordinate space. When the ArcGIS projection file is also present, the CAD file has a complete spatial reference.

Preferred Ways to Organize CAD Data for Use in ArcGIS

GIS data is organized into feature classes. Each GIS feature class has a homogeneous geometric type (all points, lines, or polygons). When building CAD drawings, it is useful to be able to isolate objects that can be candidates for GIS features. There is a great deal of flexibility within CAD to organize data. CAD data is commonly grouped by CAD layer name, different CAD files, or CAD graphic properties such as color or line style. Often all of these methods are employed in combination.

ArcGIS has several methods for categorizing and isolating data contained in CAD files. The key to successful use of CAD data as ArcGIS features is the ability to uniquely and consistently categorize different objects within the CAD file that can be used within ArcGIS feature classes. ArcGIS can directly use the geometry of the CAD objects as the ArcGIS feature geometry once the correct features have been successfully identified in the CAD file.

Implementing a CAD Standard

Implementing a CAD standard improves the quality of the CAD data and its usefulness as GIS content. A CAD standard can be little more than a plan for which objects are to be drawn on which CAD layers. The most important aspect of implementing a CAD standard is using and enforcing the CAD standard. Simple standards generally work better for this reason.

Use of seed files that already contain the proper layer names and default symbology can help. There are also third party CAD applications and some tools included in both AutoCAD and MicroStation that assist the CAD professional in the use and enforcement of CAD standards. A CAD standard is the closest thing in CAD to a GIS database schema; although it is generally up to a CAD professional or controlling application to enforce the use of the CAD standard within a CAD file, the files created with a CAD standard are more consistent, better organized, and more useful as GIS content.

Even the best documented and well thought out CAD standard is of little use if the CAD operators fail to use them and/or CAD managers do not require compliance from their own staff or in submittals from outsiders. It is far easier to draw a poorly formatted drawing than a well-formatted drawing. It is, however, easier to edit, modify, and use a well-formatted CAD drawing.

When CAD standards are only partially adhered to, data quality can actually be worse than had no CAD standards been attempted. You might make assumptions you normally would not make by simply viewing the pictorial representation of the data; new forms of ambiguity arise such as objects drawn on the right layer with the wrong color or the wrong layer with the right color. Is the color right and the layer wrong or vice versa? The adoption of a CAD standard will likely address all of the other suggestions contained in this document.

Organizing Unique Data Systems by CAD Layer

ArcGIS can easily isolate the objects within a CAD file by layer. ArcGIS uses the geometric feature type as the primary organization tool for ArcGIS CAD feature classes. ArcGIS also uses the CAD layer property to limit objects within CAD feature classes as a property of the CAD feature class. Furthermore, a definition query utilizing any of the CAD graphic properties can be used to further isolate objects within a CAD file.

A standard ArcGIS feature layer shares a single set of tabular attributes. Thinking about what types of attributes might be stored on a group of objects might help you decide what defines the granularity of a particular data system. For example, if you are drafting the underground utilities for a building project, you could make the decision to draft all the underground utilities on a single CAD layer called *utilities*. Lines could then be drawn to represent the water, storm sewer, and sanitary sewer systems and the telecommunication, cable television, and electrical distribution lines all on this *utilities* CAD layer. If the goal of the project is to simply avoid all of these features, this might work for the purpose of the CAD drawing. However, if a user is locating and drafting all of these different data systems, it would be of greater value to a GIS user to be able to distinguish between all of these different types of underground utilities by putting each different type on its own CAD layer.

Modifying CAD Graphic Symbology to Distinguish Between Different Classes or Types of Objects in a Single Data System

Vary the color, line style, or width of a symbol in CAD when drafting different kinds of the same object. One could also use the CAD layer to further distinguish between types of objects in the same data system. ArcGIS has the ability to access most of the graphic properties of CAD objects including the color, layer, line style, width, thickness, and rotation. Consistent use of varied graphic symbology can be used in ArcGIS to differentiate between features. These symbolic variations can be leveraged in ArcGIS and even replaced with enumerated descriptive tabular attributes in a GIS data set using ArcGIS software's database manipulation tools. For example, you could replace the color red with the meaning of the color red in an ArcGIS feature attribute table.

Variation in symbology is a useful form of CAD attribution only if the information coded in the CAD standard is known. White, blue, and green lines are not meaningful to GIS inherently, but if it is known that white lines are PVC water pipes, green lines are concrete sewer pipes, and red lines are ductile iron water pipes, that symbology can be useful for building GIS content.

Preferred CAD Geometric Constructs

The fundamental GIS geometric constructs of a feature class are composed of points, lines, or areas. Each feature in an ArcGIS feature class has a database table record, and may have geometric constraints or relationships with other features in the feature class or other feature classes. To enable some of the advanced ArcGIS spatial analysis and modeling functionality, feature classes adhere to various business rules that ensure the consistency and conformity to various geometric rules such as those defined by topology. The closer a CAD file's data constructs are to those of ArcGIS software's feature classes, the easier and more useful that geometry will be for use in ArcGIS.

- Create all objects within a single data system with a consistent geometric type. ArcGIS organizes its feature classes into geometric collections with a homogeneous geometric type: all point, linear, or polygonal features. This convention is not required in CAD, and CAD professionals are at liberty to create representations of

data systems using any number of different geometric types. When building a linear network, for example, use all linear features. Avoid using objects that will be interpreted by ArcGIS as points or areas when building the representation of a linear network.

Likewise do not use linear features or area features to denote objects that will be considered point features by GIS if possible. Using blocks or cells can give the CAD user flexibility to create point symbology while at the same time know that the object will be interpreted by ArcGIS as a point feature. If you are creating a point symbol by using two crossed lines, ArcGIS will see the CAD data as two lines rather than as a point symbol. The same cartographic representation of two crossed lines could be created as a block or cell symbol in CAD that is interpreted by ArcGIS as a point.

- When building a network of linear features, connect lines at or through their intersections using CAD snapping tools. When drafting linear networks, care should be taken to ensure lines that are supposed to be connected are snapped together using CAD's snapping tools; this will allow direct use of the CAD file as viable network information. ArcGIS includes many tools to automate the process of fixing such errors, but care should be taken to avoid errors that make the data unusable without modification.
- When building a network of linear features where direction may be a factor, draw linear objects in the direction from start to finish or uphill to downhill, for example. There are many tools in ArcGIS to assist in setting various direction parameters within a linear network, but care should be taken to draw objects in their intended direction for simple networks where a single primary direction may be important such as a storm sewer or other drainage system.
- When building a polygonal network, create closed polygons using CAD snapping and/or drawing cleanup tools. To construct area features with CAD, use closed polylines that will be interpreted directly by ArcGIS as areas. Simple linear networks can create visual boundaries of areas, but they are not drawn as closed polygons. Although it is much easier to draw lines with separate segments, ArcGIS will interpret these boundary segments as linear features rather than as the inferred areas.

There are tools in ArcGIS to create polygons from lines; however, for ArcGIS to interpret CAD objects without translation as polygons, you should draft polygons in CAD as closed polylines, circles, or ellipses.

- When building a linear network to represent the boundaries of a polygon network, snap all lines to their intersections. When it does not make sense to build polygon objects as closed polylines, such as in the case of a large parcel map where there is a need to distinguish between lot lines and block lines or right-of-way lines, you should be careful to snap lines together at their intersection points to avoid creating sliver areas from lines that do not close together. Furthermore, failure to snap lines together can cause the resulting boundary network to have gaps in the boundaries or short line segments to extend past the closed area boundary. ArcGIS can fix these

types of boundary errors, but to avoid ambiguity and to improve accuracy, care should be taken to draft the boundaries using proper CAD snapping tools.

Preferred Methods of Encoding Attributes on CAD Objects

Creating CAD Objects Linked to External Database Files

You may not have full control over how data is created; however, if you do, consider entering feature attributes in an external file where data entry can be easily managed and stored. The CAD forms of attribute storage and encoding can be more difficult and less reliable than simply entering the data into a database from the beginning. The key to establishing a link between objects in a CAD file and attribute records in a table is to provide a unique database link value that exists both on the object within the CAD file and in the record of the external database table.

- Use the standard database-linking tool in MicroStation to store element attributes in an external database. In MicroStation the preferred method of storing attributes in an external table is to use the MicroStation database connection tools that create MsLink and MsCatalog values on elements. The MsLink and MsCatalog values are stored on the element identifying the table and the record number of attributes stored in external files. ArcGIS recognizes these values, and the external tables can be rejoined in ArcGIS to make the same table links in ArcGIS.
- Use AutoCAD SQL Extension (ASE) external database linking techniques or object data to create external database links and include the drawing path and AutoCAD entity handle as column attributes in the external feature attributes table. Unlike MicroStation, the standard methods of establishing links between AutoCAD entities and external database tables may include proprietary internal data structures that are not readily discernable by applications that work outside of the CAD drawing such as ArcGIS; therefore, there may not be enough information readable on a CAD object to reestablish the links in ArcGIS to the external database tables. To get around this difficulty with AutoCAD, you can add the AutoCAD entity handle and the drawing name to create a set of unique attributes upon which external files can be joined to CAD files within ArcGIS. If this is done, the standard database tools to manipulate ASE or AutoCAD Object data can be used.
- Export to a shapefile. Although not technically a CAD data creation technique, any CAD data creation strategy that results in the creation of an ESRI shapefile is worthy of consideration if it fits easily into your work flow. AutoCAD Map, MicroStation Geographics, and a host of other third party CAD-based extensions can create ESRI shapefiles. Shapefiles are the de facto interchange format for GIS data and the native file format of ESRI's ArcView software. Because the shapefile is a GIS data format, any application or software add-on that generates a shapefile is directly usable as GIS content since it conforms to all the characteristics of GIS data.

One notable exception to this recommendation is data that contains curve geometry, which is not supported in the shapefile. ArcGIS does support circular and splined

curves when reading CAD files directly and can likewise store curves within the geodatabase. Therefore, a shapefile should be avoided when moving data with curves into a geodatabase. You should pursue one of the other methods when you desire to retain curve geometry with ArcGIS.

Preferred Methods of Encoding Attributes on CAD Objects Inside the CAD File

It is often useful and necessary to create attributed CAD drawings where all of the feature attribute information is stored within the CAD file. In such cases, you must make use of the various attribute-encoding methods that store data inside the CAD file with no external files.

- Use of MicroStation tags. MicroStation uses attribute tags on cells as well as on its other forms of geometry. Attribute tags have a logical name that is interpreted by ArcGIS as a column name and its value as a feature attribute. Unlike TEXT, which is an autonomous unnamed object with no links to any object it may describe, the MicroStation attribute tag is interpreted by ArcGIS as a named attribute of a CAD object. MicroStation attribute tags can be used on point, line, and polygon elements and are the preferred method of attribution within a MicroStation design file for use by ArcGIS.
- Use block inserts and cells with attribute tags rather than POINT or TEXT entities. AutoCAD Blocks insert and MicroStation cells with attributes are preferred over simple point features, which have no inherent form of feature attribution. Likewise you should consider using block inserts or cells rather than text. Attribute tags added to block inserts or cells have a logical name that is interpreted by ArcGIS as a named feature attribute. Furthermore, the cell or block insert itself has a logical name and is also interpreted as a feature attribute within ArcGIS.
- You should consider using a block insert or cells with attribute tags instead of text whenever possible and especially when it is used as a form of attribution, since the attribute tags have the same look and function as text but also have a logical name and can be modified by a single change to the block definition. Furthermore, a block insert and tag sets can contain a collection of attribute objects that can form groups of annotating features and can more easily be identified within ArcGIS because both the group and each attribute tag has a name that is read into the ArcGIS feature attributes table.
- Using AutoCAD block inserts to describe lines and areas. Place an AutoCAD block insert symbol nearest a line it describes or within the boundary of a polygon. (This method requires that a spatial join be performed to link the linear feature to the attributes of the block insert point feature or some other translation process within ArcGIS.) Placing an AutoCAD block on the inside of a polygon or at a consistent location nearest a line feature will help limit the possibility of ambiguity between which block insert belongs to which line or polygon feature. The AutoCAD block insert is preferred over text entities, since only a single text value could be used at one time to describe a line or polygon feature. Also, text entities do not have a logical name such as a block insert name or tag name from which to identify and isolate its value from within ArcGIS.

CAD Data Creation and Attribution Techniques to Avoid

The following is a list of CAD objects and data construction techniques that cause ambiguity or other difficulties when accessed by ArcGIS. These techniques and methods may be sound practice and ideal solutions for a CAD file's primary purpose; however, they are listed here to identify their impact on the CAD data's future usefulness in ArcGIS.

Multiple Text Values Denoting Different Attributes of a Single Feature

Avoid using more than one piece of text inside a polygon to denote a parcel identification number and a block group and where the text object is on the same layer, has the same color and text style, and has no other distinguishing characteristics. Although a sophisticated translation routine may be able to sort out which value is which, it introduces unnecessary ambiguity. Consider using a block with attributes instead or at least make the two forms of text distinguishable by varying the layer, color, or some other property.

CAD Dimension Entities

ArcGIS does not support CAD dimension entities; they should, therefore, be avoided as a primary attribution method.

AutoCAD Groups

AutoCAD groups are a convenient way to associate an assembly or collection of objects and deal with them as a single object within AutoCAD, without encoding them into a block. ArcGIS applications do not recognize AutoCAD groups; they should, therefore, be avoided as a primary data system organization method.

Advanced Three-Dimensional Shapes

Many forms of three-dimensional data are readily usable as an ArcGIS data source. Polylines with elevation, three-dimensional polylines, three-dimensional faces, three-dimensional points, and lines with elevation are all usable as three-dimensional GIS data sources.

To be avoided are vertical lines and planes, polygon meshes, and three-dimensional solids, which are not supported in ArcGIS.

Non-ADE Style Extended Entity Data

Not all ArcGIS applications support XData in any format; therefore, they should be avoided. Non-ADE style XData does not contain a logical name, such as a "tag," and is, therefore, more ambiguous and should be avoided. ArcGIS CAD translation tools can interpret ADE Style XData and use the ADE style tag name as the column name.

ArcGIS CAD translation tools can use all forms of extended entity data, but knowledge of the extended entity data's structure is necessary to make that information meaningful in ArcGIS.

DRMS Data

ArcGIS applications read MicroStation DRMS data, but its implementation is limited to the data that conforms to the MsLink format. Other uses of DRMS or user data are not fully supported.

ArcGIS translation tools can expose the legacy DRMS data or user data; however, you should consider using tags or external database MsLinks for the coding of new attributes in MicroStation.

XML Strings

Although there may be some potential in the future to use this or a similar attribute-tagging format, ArcGIS applications do not currently recognize XML tags of any kind; therefore, they should be avoided as the sole form of attribution.

Line Networks With Artificial Gaps for Labels or Symbols

Avoid breaking lines for annotation. Extra work is required to mend the lines in ArcGIS, and it is sometimes ambiguous how the lines should be rejoined once they are broken. Try to use other cartographic tools in CAD to create text or symbol *knockout* for plotted drawings such as a textmask or wipeout.

Line Networks With Artificial Gaps to Display Nodes

Avoid breaking lines at nodes in linear networks. Extra work is required to mend the lines in GIS, and it is sometimes unknown how the lines should be rejoined once they are broken. This technique is common in utility maps, for example, when—for cartographic reasons—lines stop short of connecting to make room for the node symbol. This should be avoided. You must consider not only the schematic, pictorial representation of the data but also the geometric interpretation of connectivity when the drawing is used as a GIS data source. Try to use other cartographic tools in CAD to create text or symbol *knockout* for plotted drawings such as a textmask or wipeout.

Custom CAD Fonts

CAD vector fonts, such as those defined in AutoCAD .shx files, may not have an ArcGIS equivalent. To ensure consistency between CAD and GIS where consistency between fonts is needed; use TrueType fonts that are supported by both the CAD system and ArcGIS.

Summary

ArcGIS software-compatible CAD data will have been created with data systems that can be differentiated from each other. The CAD data will contain a reliable, clear attribution. In addition, ArcGIS software-compatible CAD data will contain useful, meaningful attributes with accurately connected networks.

The simplest suggestion for making CAD data more useful as GIS content is to implement and adhere to a CAD layering standard. Being able to reliably identify different data systems by layer name will ensure that you can consistently identify various data systems in your CAD files. CAD drawings that are well formatted have a greatly improved value as a reusable asset. If possible, consider how drafting standards and element construction can improve the use of polygon and linear networks if viewed in GIS. Finally, when possible, use a reliable attribution scheme supported by ArcGIS to store feature attributes.

CAD applications are far too varied to even attempt to cover all of the possible attribute methods and techniques that could and/or should be implemented or avoided. Being aware that CAD drawings may have value as GIS content helps to create data in a way that makes the data more useful as GIS content.



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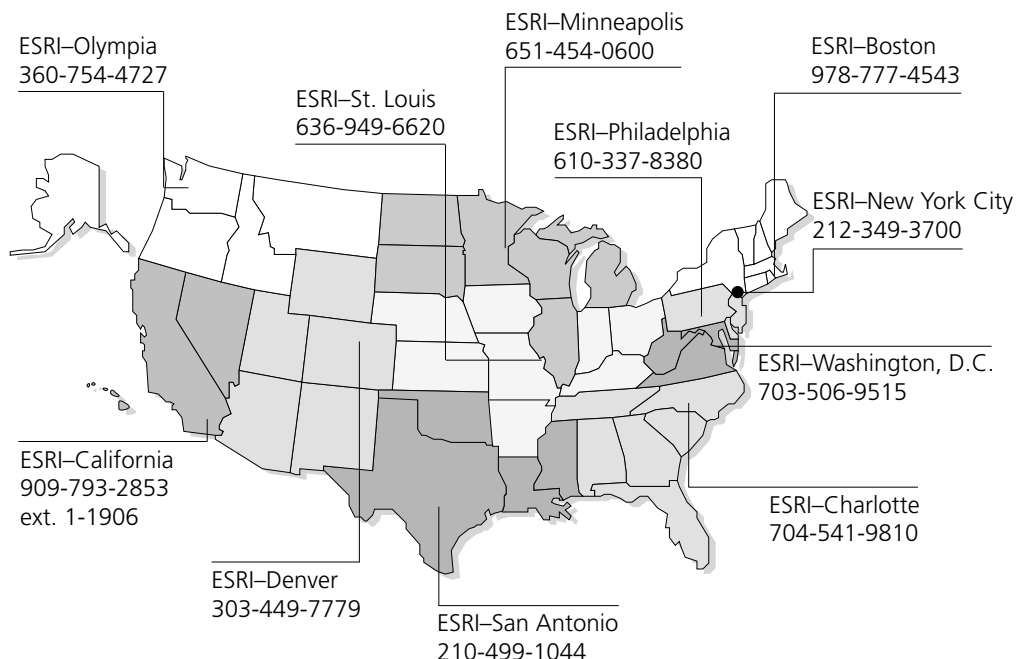
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