
Building A Custom GIS-Based Precincting and Redistricting System

A Body of Knowledge From the Los Angeles County Experience

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Co-Authors:

Kenneth Bennett, Section Head – Geographic Information Systems
R. Vern Cowles, Division Mgr., Precincting, GIS, and Election Tally Systems
Michael Petrucello, Asst. Registrar-Recorder and CIO

The Los Angeles County Registrar-Recorder/County Clerk



12400 Imperial Highway
Norwalk, CA 90650
Tel: (562) 462-2986
E-mail: kbennett@rrcc.co.la.ca.us

Table of Contents

1.	Background.....	1
1.1.	History of GIS at RR/CC: 1980 - 2000.....	1
1.2.	Advances in GIS at RR/CC: 2000 – 2005	2
1.3.	Sharing A Body of Knowledge.....	3
2.	The Registrar of Voter’s Need for GIS.....	4
3.	Building the GIS-Based Precincting and Redistricting System.....	7
3.1.	Data Requirements and Development	7
3.1.1.	The Precinct Layer.....	7
3.1.2.	The District and District Type Tables.....	9
3.1.3.	The District Assignment Table	10
3.1.4.	The Street Segment Layer.....	11
3.1.5.	Other Background Reference Layers.....	15
3.2.	Work Flow and Quality Control	16
3.2.1.	Versioning.....	16
3.2.2.	Topology.....	19
3.2.3.	Database Synchronization and Systems Integration.....	19
3.3.	Core Functional Requirements	20
3.3.1.	Precinct Editing Functionality	20
3.3.2.	Street Segment Editing Functionality	20
3.3.3.	Administrative Functionality	21
3.4.	User Skills and Training	21
3.5.	Project Planning and Scheduling	22
3.5.1.	Phase 1 - Data Development, User Training, Implementation Planning.....	22
3.5.2.	Phase 2 – Implement Administrative Functionality.....	22
3.5.3.	Phase 3 - Implement Precinct Management Capabilities.	23
3.5.4.	Phase 4 – Implement Street Segment Management Capabilities.....	23
3.5.5.	Phase 5 - Develop Precinct and District Mapping Capabilities.....	23
3.5.6.	Project Scheduling	23
4.	Conclusion	24

Abstract

In 2000, the Los Angeles County Registrar-Recorder/County Clerk (RR/CC) embarked on the implementation of a custom GIS for precincting and redistricting that integrated with RR/CC's voter and election information management systems using GIS software from ESRI. Originally envisioned as a year-long project that would deploy the system in time to support the implementation of the 2000 decennial Census reapportionment, challenges related to data development and maintenance, software programming, and systems integration postponed full production release of the system until 2003. After five years, RR/CC has accumulated a body of knowledge about best practices and pitfalls, tips and tricks, surrounding the implementation and maintenance of a custom precincting and redistricting GIS. This paper addresses many topics including: data requirements and development; core functional requirements; work flow and quality control; user skills and training, and project planning and scheduling. This paper is especially geared toward agencies who are interested in using a GIS to support the implementation of the upcoming 2010 decennial Census reapportionment.

1. BACKGROUND

The Los Angeles County Registrar-Recorder/County Clerk (RR/CC) has a relatively long history of using GIS technology to support its mission and goals. From the original purpose of maintaining precinct boundary lines and producing state-mandated precinct maps, RR/CC has expanded its use of GIS technology to support voter precincting, election consolidation, poll location and the production and distribution of a broad range of geopolitical and election-related maps. For RR/CC to get to its current level of sophistication in the application of GIS technology, several developments in hardware, GIS software, and GIS data had to take place. The following sections provides a brief history of GIS technology usage at RR/CC, and make the case for why Registrars of Voters need GIS to support their operations.

1.1. HISTORY OF GIS AT RR/CC: 1980 - 2000

Prior to the advent of computers and GIS technologies, the County's state-mandated precinct maps were hand-drawn by draftsmen at the Department of Public Works (DPW). By the 1980's, computer technology had progressed and DPW was using Computer Automated Drafting (CAD) technology to generate digital versions of the precinct maps, but still at considerable cost to RR/CC. In the early 1980's, geographic information system (GIS) software maker Environmental Systems Research Institute (ESRI) released its flagship GIS product, Arc/INFO. This product initially ran on minicomputers, and then UNIX workstations, whose cost prevented wide proliferation of GIS technology. By the late 1980's, ESRI had developed a limited version of Arc/INFO for the popular PC platform, and by the mid-1990's, released a full featured version of Arc/INFO for Microsoft's popular Windows NT workstation.¹

This convergence of GIS and Windows NT technologies made it affordable for RR/CC to implement its own GIS on a Windows NT network. The initial application of GIS had two objectives. The first was to use GIS to maintain a precinct boundary layer that geographically represented the alphanumeric precinct file being managed in the mainframe election management system. The precinct boundary layer was first created from DPW's CAD system by converting it to an Arc/INFO coverage. Thereafter, native Arc/INFO tools were used to update the precinct boundary lines whenever a change occurred in the mainframe system. The second was to begin the in-house production of the state-mandated precinct maps. In 1995, RR/CC developed its first custom GIS application for automating precinct map production called the Map Creation System Interface (MCSI). With these applications of GIS technology, the department saved tens of thousands of dollars annually in map production costs and associated boundary line management that formerly was paid to DPW. Around the same time, RR/CC also created a custom District Plot application for automating the creation of district maps requested by County officials and the public. A routine was written to extract the district assignments for each precinct from the mainframe system, and this data could then be joined to the precinct boundary layer. With this information, the District Plot application could extract precincts based on a specified district assignment value, and then dissolve them into the desired district boundary. Both the MCSI and District Plot applications were developed using ESRI's proprietary programming language called Arc Macro Language (AML).

¹ ESRI Website, 2005, ESRI History, <http://www.esri.com/company/about/history.html>, accessed 12 July 2005

One important key for maintaining the precinct boundary layer and making accurate precinct maps was having reliable and accurate spatial reference layers in GIS format. The most important layers for determining precinct and district boundaries are streets (including address ranges), land parcels, and Census tracts and blocks. When the adoption of GIS in the County first began in the late 1980's and early 1990's, the County Assessor's office had no land parcel data in GIS format and would not complete one for another decade. The Census Bureau's TIGER system had just been developed in the mid-1980's and was first used during the 1990 census², but the notorious spatial inaccuracies of the TIGER/Line data restricted its use. Many commercial GIS data vendors, however, were developing street layers with varying spatial and attribute accuracy. As the technology at the time made it unaffordable for the County to create and maintain its own street layer, a debate began to take shape over which GIS data vendor should be used to supply the County with a reliable street layer. Several vendors were considered, and each one had its advocates among the County's departments. The debate was finally settled by the 1993 Northridge Earthquake. GIS technicians staffing the emergency operations center during the aftermath of the earthquake discovered empirically in their analysis and map production that the GIS data provided by Thomas Brothers was more accurate than other vendors, and the County ultimately entered into a licensing contract with Thomas Brothers that continues to this day.

With time, however, it became evident that even Thomas Brothers GIS data lacked the completeness and accuracy necessary for GIS operations in the County, and Thomas Brothers' mechanism for updating the data was not responsive enough to keep up with Los Angeles County's ever growing and evolving transportation network. In 1999, RR/CC led a multi-department project to develop its own GIS system for updating Thomas Brothers' transportation data. This countywide system, called the Transportation Updating System (TUS), was deployed in 2001, and to this date has improved the transportation layer with over 160,000 edit transactions. The success of this system earned it an Achievement Award in 2004 from the National Association of Counties (NACo).

By the close of 2000, RR/CC had developed several other GIS applications for supporting its operations. A Precinct Consolidation application was developed to create election ballot groups and consolidations. GIS applications were developed for locating polling places on the Los Angeles transportation network, identifying potential polling places for upcoming elections, and for generating maps of adjacent precincts used by polling place staff during elections to direct voters to their correct polling places. A Web-based GIS application called the Polling Place Locator was also developed to help voters find their polling place during an election by entering in their address. These applications were developed using third-generation, object-oriented software, including Microsoft's Visual Basic programming language and ESRI's MapObjects GIS software components.

1.2. ADVANCES IN GIS AT RR/CC: 2000 – 2005

In 2000, RR/CC began a project to further integrate GIS into its precincting and redistricting operations. Up to this time, GIS was a post-process tool for moving precinct boundary lines and

² U.S. Census Bureau Website, 2005, TIGER, TIGER/Line, and TIGER-Related Products, <http://www.census.gov/geo/www/tiger/index>, accessed 12 July 2005

generating new precinct maps after those lines had already been “moved” through the voter precincting process, which now took place in RR/CC’s new Windows-based election management system called the Voter Information Management System (VIMS). In essence, RR/CC had a double entry system in which precinct boundaries were edited once in VIMS, then again in the GIS for producing precinct maps.

With ESRI’s 1999 release of version 8 of its Arc/INFO product (now called ArcGIS Desktop to distinguish it from its Workstation predecessor), as well as the ArcSDE software for storing spatial data layers in a relational database, RR/CC saw the opportunity to streamline precincting operations by implementing a new enterprise, transactional GIS database for maintaining precinct boundary lines, precinct district assignments, and street address ranges, and then pushing those edits into VIMS. Whereas the process of precincting voters had involved manually marking up hard-copy precinct maps to determine which street address ranges would be assigned to which precincts, making the edits in VIMS, and then repeating the edits in the GIS, the new GIS, appropriately called the Single Point Data Entry (SPDE) system, allowed the edits to be made once in the GIS. SPDE eliminated the cumbersome and costly handling of hard-copy maps from the precincting and redistricting processes, greatly reduced the time needed to analyze and edit precinct boundaries, street address ranges, and precinct district assignments, and introduced automated validation routines to ensure data integrity, streamline voter precincting, and to respect required data lockdowns during elections.

During the phase-in of the SPDE system in 2002-2003, RR/CC embarked on another GIS project to replace the MCSI application with a new Precinct Mapping application based on the new GIS technology and fully integrated with the new SPDE enterprise geodatabase. This application takes advantage of the object-oriented architecture of the ArcGIS software to allow users to make incremental modifications to the precinct maps in response to underlying data edits, instead of recreating the entire map from scratch, as was required in the MCSI, greatly reducing the map production cycle. The new Precinct Mapping application also includes the capability to create precinct maps for previous elections using historical precinct and district data stored in the SPDE geodatabase, and to store and print maps in the universally recognized PDF format.

In 2005, RR/CC began another project to replace the old District Plot application with a new District Mapping application based on ArcGIS 9, and Visual Studio.NET that similarly integrates with the SPDE geodatabase. The Precinct Consolidation and other MapObjects-based GIS applications are being reprogrammed to access data from the SPDE geodatabase as well.

1.3. SHARING A BODY OF KNOWLEDGE

While RR/CC is proud of its history and depth of experience in applying GIS technology to its operations, the going was not always easy. Like many organizations who are early adopters of GIS in their respective field, RR/CC had to blaze a new trail when it came to applying GIS to the many and complex activities typically carried out by a Registrar of Voters. Over the past ten years, RR/CC has tackled many issues related to developing the required GIS data, designing custom GIS functionality for editing, validating, and mapping precincting and redistricting data, training staff, and integrating GIS with existing election management systems.

Recently, RR/CC has become aware of other Registrars of Voters interested in using GIS, and believes the body of knowledge it has accumulated may be beneficial to those agencies considering a custom implementation of GIS for precincting and redistricting. The following sections provide an overview of the important issues to be considered, and special emphasis is placed on the timing of a precincting and redistricting GIS implementation for the upcoming decennial census.

2. THE REGISTRAR OF VOTER'S NEED FOR GIS³

The Registrar of Voters' job of determining where voters reside, and consequently what candidates and initiatives they can vote for during an election is an ongoing process, largely because election-related geography is continually changing between elections. Precinct boundaries change due to fluctuations in a neighborhood's number of voters, changes in jurisdictional boundaries, and the redistricting process resulting from the release of new Census Bureau data. The keys to successfully managing this process are to maintain accurate and accessible information about the spatial distribution of voters, precincts, and districts, and to integrate this data with other election information systems.

Many Registrars of Voters have already automated their election processes with the help of election information systems that store tabular data in electronic files or in relational databases. Most of these systems, whether home-grown or purchased from software vendors, typically rely on a data schema that relates a voter record to an address range on the local street network. This address range, or street segment, in turn is related to the precinct in which it is located. The precinct itself is related to a list of districts having jurisdiction over the area encompassed by the precinct. With this schema, voter precincting is a two-part process of maintaining the relationship between street segments and precincts on the one hand, and matching a voter to a street segment using the voter's address on the other.

The advantage of this schema, particular for populous metropolitan areas such as Los Angeles County, is that voters can be precincted in an aggregated manner using the street segments. For example, in Los Angeles County where there are approximately 4 million voters, precincting staff can manage voter's precincts by maintaining approximately 500,000 street segments. Another advantage is how closely it models reality. As Figure 1 below illustrates, the logical relationship of data entities in this typical ROV data schema mirrors the spatial nesting of the voters, street segments, precincts, and districts in the real world.⁴

³ This section is adapted from a bd Systems, Inc. white paper titled "Integrated Data and Workflow Management for Registrars of Voters Using Geographic Information Systems (GIS)", which I wrote back in January, 2003.

⁴ RR/CC recognizes that not all states in the U.S. require counties to adopt the data schema or business processes such as those described here, which are required of Los Angeles by the State of California. Some states or counties may not require the editing or sub-dividing of precincts to adjust district boundaries. Others may not require street segments to place voters in their precincts. This paper does not intend to suggest that the data schema or other aspects of the GIS described herein are the correct way, or the only way, to build a precincting and redistricting GIS, and it is hoped that those agencies with different requirements will still be able to learn some helpful tips from the Los Angeles County experience.

Logical Relationship of ROV Data Entities



Spatial Relationship of ROV Data Entities

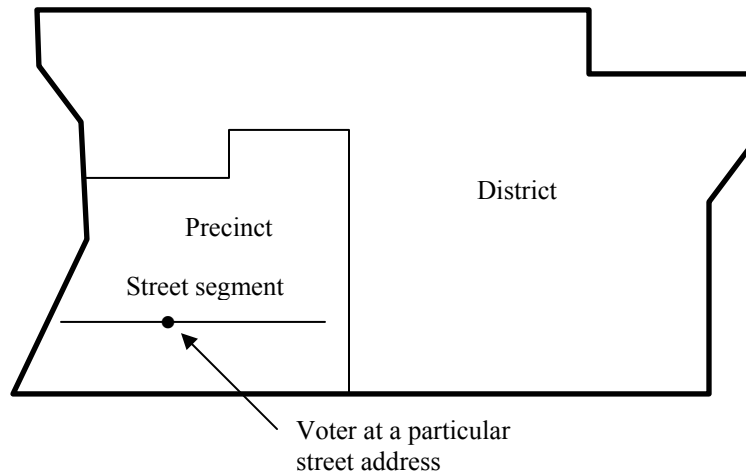


Figure 1. The Logical and Spatial Relationship of ROV Data Entities

Even with the help of election information systems, the process of managing these complex spatial relationships would be very difficult without the use of maps. When district boundaries change, the new district alignments may run through the middle of one or more precincts, which in turn must be split to accommodate the new alignments. If the number of voters in a precinct becomes too large or too small, the precinct must be split, or merged with another precinct, to maintain an acceptable precinct voter count. Precinct boundary changes also affect street segments. Moving a boundary over several blocks in a neighborhood means that some street segments must be reassigned from one precinct to another. Occasionally, precinct boundary changes will run down a parcel boundary in the middle of a block over to the next block, effectively splitting a street segment. Needless to say, these district precinct and street segment maintenance processes are very map intensive, and in fact Registrars of Voters have been using maps as a vital part of their operations for a long time. They are a source of all geographic features (street names, address ranges, city limits, zip code zones, census tract boundaries, parcels, among others) which are used as points of reference in describing redrawn districts boundaries, identifying precinct for maintenance, and splitting and merging street segments.

Because of this need for maps to support precincting and the redistricting processes, as well as other requirements to publish hard copy precinct and district maps for the public, election information systems have a natural affinity to geographic information system (GIS) technology. Many Registrars of Voters have recognized this fact and have begun adopting GIS technology,

but unfortunately have limited its use to the production of maps. While GIS technology is indeed an excellent tool for map production, this stereotypical and limited view of GIS significantly underutilizes the technology, and fails to leverage some of its greatest benefits. Using GIS as a reporting system that receives data from the election management system, instead of as a data maintenance system in its own right, has three major failings. First, the election management system that maintains the data does not maintain the spatial component (i.e., the geometry) of the data, so in order to incorporate data updates into the GIS to support map production, the data edits must be entered a second time into the GIS. Second, this double entry of data is prone to human error that results in data inconsistencies between the GIS and the election management system, and lost productivity due to confusion and error correction. Last, and perhaps most important, it fails to take advantage of the spatial analytical capabilities of GIS, which can be used to automate and streamline the maintenance and validation of election-related data. The result of these failings is that work loads increase and drive up the total cost of ownership of the technology.

The solution is to implement GIS as a front-end election data management system that enables users to make their original edits to precincts, districts assignments, and street segments directly through a digital map interface. There are multiple benefits of using GIS as a data maintenance tool in the precincting and redistricting processes. These include:

- Precinct and district boundary edits are made only once through the GIS interface, making workflow more efficient and reducing redundant data entry and facilitating quality control. Reducing the staff hours required for data entry frees more time to perform other critical business tasks.
- The maintenance of the relationship between precincts and street segments is incorporated into the precincting and redistricting workflow. When precinct boundaries are changed, affected street segments are automatically linked to the new precinct.
- Spatial validation processes provide better support for maintaining the accuracy and integrity of data. In particular, by displaying street segments as map features, street segments are linked to the precincts in which they are located, thus ensuring that a street segment won't be moved into an incorrect precinct.
- Visualizing the street segment data on the map can highlight data anomalies that would otherwise be "hidden" in a strictly alphanumeric election management system.
- Data maintenance through a map interface means less reliance on hard copy maps, which are costly to purchase or make, and time-consuming to organize and use.
- The GIS-based precincting and redistricting system becomes a central framework for developing other important election-related applications, such as precinct and district mapping tools, internet mapping, polling place locators, and applications for planning the distribution of polling supplies and ballots to and from polling places.

3. BUILDING THE GIS-BASED PRECINCTING AND REDISTRICTING SYSTEM

There are several aspects of a GIS-based precincting and redistricting system that must be considered and understood in order for one to be successfully implemented by a Registrar of Voters. These include the GIS data requirements and development, work flow and quality control, the core functional requirements, user skills and training, and project planning and scheduling. The following sections discuss these important topics, and are based on the body of knowledge that RR/CC has accumulated over the years. Where applicable, the discussions highlight critical issues that affect those Registrars of Voters that might be considering the implementation of a precincting and redistricting GIS to support district reapportionment after the upcoming 2010 decennial census.

3.1. DATA REQUIREMENTS AND DEVELOPMENT

In order to use GIS as a maintenance tool for precincting and redistricting, the system must contain the following data:

- A precinct layer (polygons)
- Tables of the districts and district types (alphanumeric)
- A precinct district assignment table (alphanumeric)
- A street segment layer (polylines)
- Other background reference layers (point, polyline, and polygon)

It is assumed that most Registrars of Voters use the data model described in Section 2 above, and therefore will have access to this data, at least in alphanumeric format, from the election management system. Those Registrars of Voters that are already using GIS for mapping will likely have the precinct layer in GIS format already, and that this precinct layer will be related in one form or another to the corresponding district and district type data through a district assignment table. Without this information, it would be extremely difficult to generate the district boundaries for a district type, or an individual district, unless it were done manually, which would be inefficient and time-consuming.

Since it is highly unlikely that the street segment data in the election management system would ever be used by a Registrar of Voter in a GIS map production tool, chances are that most Registrars of Voters will not have the street segment data in a GIS layer format. No matter what extent of GIS implementation is in place at a Registrar of Voters, it will be useful to read the following sections detailing the specific issues to be considered about each dataset.

3.1.1. The Precinct Layer

The precinct layer is a layer of polygons that represent the geographic distribution of the precincts in the election management system. If the election management system subdivides precincts into portions (a.k.a. “sub-precincts”), then the polygons will represent the sub-precincts. If the precinct layer will be maintained in a GIS system that is separate from the election management system, it is important for the precinct layer to have, at a minimum, the same set of attributes as the precinct dataset in the election management system. This will

ensure the GIS system supports election management system routines for batch importing the alphanumeric attributes of the precincts back into its database.

If the precinct data does not exist as a polygon layer in a convertible digital format, such as GIS or CADD, the sub-precinct polygons will have to be created from scratch using the polygon editing tools of the GIS system. The best methodology for doing this involves using line features from other reference GIS layers (including street centerlines, parcel boundaries, census blocks and hydrology features) to digitize the sub-precinct polygon boundaries, although the polygon boundaries could be digitized in a freelance manner by looking at hard copy maps.

To begin the precinct layer digitization, start with a GIS layer of the county boundary and add a field for storing the sub-precinct number, as well as other temporary fields for tracking the progress in creating and validating the precincts throughout the data development effort. The digitizing of the precinct layer is best done one sub-precinct at a time until all sub-precincts have been digitized. To digitize a single sub-precinct using ESRI's ArcMap interface, complete the following suggested set of steps:

- Identify the sub-precinct to digitize on hard copy maps, drawings, or metes and bounds descriptions for districts
- Locate the approximate location in ArcMap (bookmark if necessary)
- Start an edit session, set task to "Create New Feature", and set the target layer to the sub-precinct layer
- Review boundaries for connectivity, in some instances additional lines may need to be hand digitized (change target layer)
- Select the line features that define the sub-precinct boundaries
- When selection is complete, use the "Construct Features" tool on the topology toolbar to build the new sub-precinct polygon
- Select the new sub-precinct and enter the sub-precinct number and other tracking attributes
- Save edits
- Stop the edit session

It is estimated that initial digitizing efforts may take 45 – 60 minutes per sub-precinct, including review of reference data and digitizing of the sub-precinct polygon. As the user becomes more familiar with the process and tools the time may improve to 30 – 45 minutes per sub-precinct. It should be qualified that these numbers are a rough performance benchmark based on experience and actual performance measures may vary, depending on the size and geographic distribution of the precincts.

Once the sub-precinct layer has been created and validated, the temporary tracking fields should be deleted, and new fields mapped to the precinct table fields in the election management system should be created. The precinct attributes from the election management system can then be imported into the precinct layer in the GIS.

The total effort to digitize a precinct layer from scratch will also depend on the number of districts. Typically, the more districts there are in the county, the greater the fragmentation of

the county into a higher number of precincts. A more detailed discussion of districts and how they impact the GIS implementation is presented below.

3.1.2. The District and District Type Tables

The GIS-based precincting and redistricting system must have access to the tables that define the types of districts, and the list of possible districts for each district type, that are to be managed. These tables typically reside already in the existing election management system, and can be imported into the GIS. The list of districts will of course include all districts that require an election contest to seat an elected official, create a new district, or move a district boundary. However, in addition to these districts, the system must also store certain pseudo-districts that model important information relevant to special needs or functions of the Registrar of Voters, even though those districts do not represent an election contest. The data schema described in Section 2 should allow the election management system, and consequently the GIS, to model pseudo-districts. The two most common pseudo-districts are census tracts and tax rate areas.

3.1.2.1. Census Tracts

Modeling census tracts as a pseudo-district in the GIS is critical for the support of implementing the district reapportionment that occurs after the Census Bureau's release of new census data following the decennial census. Because most states base their decennial reapportionment of major districts (i.e., U.S. Congressional, state senate and assembly, etc.) on the census demographic data contained in census tracts and blocks, the geographic descriptions of the districts frequently come in the form of lists of census tracts that make up the districts. If the census tracts are modeled as pseudo-districts in the GIS, the Registrar of Voters can implement the reapportionment more quickly and efficiently by making bulk selections of precincts based on the census tract assignment, and then assigning the appropriate reapportioned district to the selected precincts. This can only be done, however, if the census tracts from the decennial census are modeled in the GIS as pseudo-districts.

For those Registrars of Voters considering building a GIS-based precincting and redistricting system to support implementation of the 2010 district reapportionment, it will be necessary to incorporate the 2010 census tracts as a pseudo-district in the GIS. For Registrars of Voters in large urban areas such as Los Angeles, this can be a considerable undertaking in itself, as it may involve the digitization of hundreds, or perhaps thousands, of census tract lines. If the Registrar of Voters already has the 2000 census tracts modeled in their system, the task may be simpler. This is because the Census Bureau provides a link, where applicable, to the corresponding census tract for that same area from the previous census a decade earlier. By correlating the list of new census tracts to those of the previous decade, the new 2010 census tracts can be more quickly incorporated into the system without lots of digitization.

Even then, bringing in the 2010 census tracts may be challenging. Census tract numbers frequently change from one decade to the next and, although they are making great efforts to improve their product, the Census Bureau geometry has historically had problems with positional accuracy. The level of effort and time required to develop and enhance this data should be taken

into consideration when planning the GIS implementation, especially if the goal is to use the GIS during the upcoming reapportionment.

Another factor to consider is that, even with census tracts available in the GIS to support bulk selections of precincts, implementing the reapportionment using census tracts will still require a significant amount of manual intervention by users. When the state reapportions a district, it is common for them to define parts of the new district boundary in terms of portions of census tracts (i.e., census blocks), or by other geographic features. In this case, it may still be necessary to manually adjust the precinct boundaries by individually merging or splitting the precincts in the GIS.

3.1.2.2. *Tax Rate Areas*

Some Registrars of Voters may want to be able to display tax rate areas (TRA) on their maps in order to provide information to voters about where their taxes are going. As noted already, the GIS should allow TRA boundaries to be modeled just like any other boundary. The TRA boundary modeled can be the *actual* boundary, as defined by the agency responsible for defining tax rate areas, or the *assigned* boundary. The *assigned* boundary would follow parcel boundaries, while the *actual* boundaries may or may not follow parcel lines, depending on who defines them and how they are defined. The process of assigning a parcel to a TRA usually follows the rule that the side of the boundary on which the majority of the parcel lies is where the parcel is assigned. But this is not a hard and fast rule, and sometimes the location of the owner's house on the parcel overrides the proportionality factor. The GIS system will allow a Registrar of Voters to incorporate either *actual* or *assigned* boundaries, or both, into the system. The main issues to consider are how much more fragmentation to the precinct layer will be caused by incorporating the TRA boundaries into the GIS, how much extra effort will be required to maintain them on an ongoing basis, and whether or not the cost is justified.

Another issue to consider with TRA boundaries is the changes in data and work flow that may be required to support TRA boundary maintenance. As with other district boundary changes, sub-precincts must be edited (i.e. split and merge polygons) to move the boundaries, and any relevant information about TRA boundaries will be a useful reference source. Some Registrars of Voters, however, may not have access to a GIS data layer of the TRA boundaries, or even hard copy maps for that matter. Whoever determines the TRA boundaries for the county may or may not have the means of generating or maintaining a GIS layer of the boundaries. Whatever the case, the Registrar of Voters will need to establish the flow of data to get the TRA boundary information, as well as the internal work flow for their ongoing maintenance.

3.1.3. **The District Assignment Table**

The table of district assignments is essentially a cross reference table that links a district record to the unique set of precincts features that make up the district, or conversely, that links a precinct record to the set of districts it represents. This data usually exists in the election management system in a similar format and can be imported directly into the GIS. This table is not only useful to extract precincts that make up a district for district mapping purposes, it can

also be used during precinct editing to validate the integrity and business rule compliance of the precincts' district assignments.

3.1.4. The Street Segment Layer

The street file in the election management system is a table whose records represents discrete address ranges where voters or polling places are located. While the election management system will likely have address range records covering most streets in the county, it may not cover *all* the streets in the county, as some streets either may not have a postal address associated with them, or may have no voters or polling places located on it. Consequently, the street file is not a true geographic representation of a continuous street network in the real world. As such, there seems on the face of it to be little incentive to geographically render the street file on a map. In fact there are probably very few Registrars of Voters who have had the need to do it, so the creation of this GIS layer is perhaps the most crucial data development task in the implementation of a GIS-based precincting and redistricting system.

3.1.4.1. The Advantage of the Street Segment Layer

The development of the street segment layer is key because it allows the GIS to display, edit, and validate the street records on a map as part of the precincting process. Recall from the discussion of the data schema in Section 2 that it is through the street segment (i.e., address range) that voters are linked to their respective precinct. If a street segment is created, or moved to a new precinct, or if a precinct boundary moves, thus bringing neighboring street segments into its circumference, the GIS must be able to determine what that new precinct is for the affected street segments. If the geographic dimensions of the street records in the election management system can be rendered on a map, then the process of relating the streets to the precincts can be managed by a spatial query that identifies the precinct in which each street segment is located.

Using a spatial query is much more intuitive and accurate than in a traditional relational system because the relationship is established not by what the user thinks is correct, but rather by the facts of the geographic relationship between the street and the precinct. If the relationship is incorrect, it can only mean that either the street segment, or the precinct boundary, is in the wrong location. This of course would be a glaring error that is easily detected in the visual environment of a map (especially if other background layers can be referenced), and in fact a GIS is very good at illustrating spatial errors that are difficult to identify in a strictly tabular system. The spatial query is also effective at street segment validation. In a situation where a street segment crosses a precinct boundary line, the spatial query will return multiple precincts. This result is ambiguous, and therefore invalid, because a voter must not potentially reside in two different precincts.

3.1.4.2. Developing the Street Segment Layer

To transform the street file in the election management system (which is essentially a table of alphanumeric records with no knowledge of geography) into geographic features in the GIS, it is necessary to relate each street record to a location on the street centerline layer for the county. The good news about this effort is that if the county has not already developed a street centerline

layer, it is usually quite easy to purchase one of reasonable quality from a commercial data vendor. The bad news is that getting to the point of having an accurate street centerline layer is just the first step in the process. The next step is to convert the street centerline layer into a measured street network that stores a feature for the left and right side of each fully-qualified street name in the county. The term fully-qualified street name refers to a street with a unique combination of street name, postal city name, zip code, and address parity values. Each of these left or right features stores the From and To address values of the street centerline features from which it was created as measure values. Figure 2 below illustrates how the street centerline layer is converted to a street network layer.

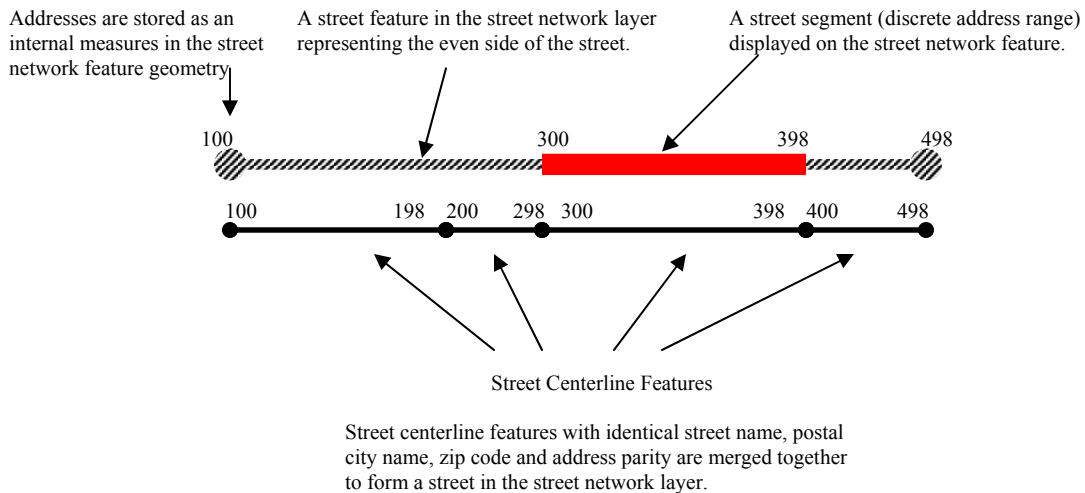


Figure 2. Relationships Between The Street Centerline, Street Network, and Street Segment Layers

There are several pitfalls in the creation of the street network that are difficult to avoid. One is that the direction of digitization of the street centerline features has a bearing on the geometric structure of the street network feature that is created. If the street centerline features do not share the same direction of digitization, or if they do not all have address ranges in which the From address is the low address, and the To address is the high address, the resulting street network feature may be composed of internal parts that flip about in the direction of digitization. Running a trace along the measures of the street network feature may reveal a From or To address that is located in the middle of the feature. Ultimately, this error in the data will be transferred to the street segment layer. Another problem is that some streets have both odd and even addresses on the same side of the street. Unless the street centerline layer stores a flag for this dual parity, the street network can only interpret the parity based upon the parity of the underlying address range. Other errors in the street centerline layer, such as repeating address ranges or incorrect street alignments, are also transferred to the street network and then to the street segment layer. If time and funds permit, the Registrar of Voter should perform a thorough quality analysis and control effort to eliminate or mitigate these data issues in the street

centerline layer, for it will save time and money later when the street segment layer is being developed and maintained.

The process that is used to convert the alphanumeric street segment record to a geographic feature involves matching the street segment to the appropriate street network record, then locating the address range of the street segment along the street network feature through a process called linear referencing. The street segment records are matched to the street network based on a comparison of the fully qualified street name of the street segment and the fully qualified street name of the street network feature. Linear referencing involves interpolating the location of a point value along a line feature based on that feature's internal measures. For records with one point measure value, the resulting layer is a point feature layer. For records with two point measure values (i.e., the From and To along a line), the result is a line feature layer. Since the street segment is an address range with a From and To address point, the resulting street segment layer is a line feature layer.

In GIS terminology, the creation of a line feature layer based on linear reference against another layer is called dynamic segmentation, and the result is called an event layer. This is because the process identifies segments of a linear network on the fly (i.e. dynamically in the computer's memory) that describe unique events (i.e., attributes of that segment at that point or along that segment) without having to physically split the underlying linear network (i.e., static segmentation) to store those unique attributes. Once the dynamic segmentation layer of the street segments has been created in memory, it can then be saved as a separate GIS layer.

The steps required to develop the street segment layer can be summarized as follows:

- Create the street network layer from the street centerline layer. Each street in the street network represents a unique fully qualified street name (i.e., identical street name, city name, zip code, and address parity values) in the street centerline layer. Since these values, as well as street address ranges, can differ on either side of the street, there is always a right-side street and a left-side street for each unique fully qualified street name in the street network.
- Match the street segment records from the election management system to the street network based on the fully qualified street name and the address range. When a match is made, the street segment is populated with the unique identifier of the street in the street network.
- Analyze the street segments that fail to match to a street in the street network. This effort will determine discrepancies in street names, city names and zip codes. Initial match efforts require that street names in the street network match precisely with the street names in the street segments. When street segments are unmatched, the cause is very often a difference in street name spelling between the street layer and street segment (see the example below). Other unmatched segments may have problems with different city names and /or zip code numbers.

Example of Spelling Discrepancies

Actual	Expected
Cabbot Rd	Cabot Rd
Spring Way	Spring Wy
Coast Hwy	N Coast Hwy

- Modify the match constraints and then re-match the remaining unmatched street segments to the street network layer.
- Display the street segments as a linear event layer in the GIS. The process of displaying linearly referenced features on the map is known as dynamic segmentation. The layer created during this process is known as an event layer. Be sure to use an offset value so that the left and right street segments can be distinguished from each other and from the street centerline layer itself.
- Convert the event layer to a stand-alone GIS layer using native GIS functionality. Once converted, the street segments can be displayed and edited just like any other layer in the GIS. Maintenance of the stand-alone street segment layer is easier than managing an event layer. There are also improvements in the time needed to render the street segments on the map display. On the other, it is important to be able to capture spatial edits to the street centerline layer periodically, so that they can be transferred to the street segment layer through the GIS interface.
- Analyze the street segments against the precinct boundaries to determine discrepancies in the precinct number recorded on the street segment and the precinct number in which the street segment actually geographically resides.
- Develop and implement a maintenance plan for fixing errors and incorporating updates to the street segment layer.

The street segment matching is a very important task in the data development effort. A successful match rate is approximately 80%, but that could leave a significant number of street segments that must be matched manually, especially in large metropolitan areas. There are several options that may be used to match additional street segments including:

- Reduce match criteria. Initial matching is based on an exact text string match between street segment name and the name in the street network. In the initial match process “N Main St” matches to “N Main St” but not “Main St”, because the second example is lacking the directional prefix. By removing the directional prefix and street suffix from the match criteria, previously unmatched street segments can be matched in a secondary match process. This methodology has the risk of causing some false matching. By excluding the prefix and suffix from the match criteria, a street segment with the name “N Main St” could be matched to “S Main Blvd”.

- Fix errors in the street centerline layer. As mentioned earlier, this will pay big dividends later during street segment development. In the case of matching, this is particularly true of the street segment attributes. Errors in street centerline feature attributes, such as spelling errors in the street name, postal city name, or zip code, or erroneous address ranges, can cause multiple street segments to fail to match to a street feature in the street network. Fixing attribute errors on one street in the street centerline layer can translate to correct matching for multiple street segment records.

Note: After the development of the street segment layer, however, it becomes much more difficult and complex to fix the attribute errors in the street centerline layer, rebuild the affected streets in the street network layer and manually match the street segment. This is because changes to the attributes on one feature in the street centerline layer can affect several street records in the street network. For example, changing one street centerline feature from Main Street to Main Court requires both the Main Street and Main Court street network features to be rebuilt. If you consider that both street names have left and right features, then a total of four street network features must be rebuilt, and numerous street segments must be matched. Other issues arise when the geometry of street centerline features are edited. Our experience indicates that trying to perform large-scale updates to the street centerline layer and then passing them through to the street network and street segment layers is neither efficient nor cost-effective. The building of the street segment layer should be viewed as a once-off development effort that requires careful planning and thorough quality analysis and control at the beginning of the process. This is also the main reason for converting the street segment event layer to a stand-alone GIS layer.

- Create a lookup table of prefixes and suffixes. Different spellings of the same prefix or suffix may cause a street segment to fail to match to a street on the street network. It is common between different datasets that the same prefix or suffix may be spelled in different ways (i.e., Blvd, Blvd., Bvd.; or Way and Wy). A lookup table can be created to translate numerous variations in the spelling of different prefixes and suffixes to a common value. The table can then be incorporated into the initial match process in an effort to increase the match rate.

Any street segments that cannot be located on the street network layer through the matching process described above can be analyzed and located manually using editing tools provided in the GIS interface for long-term street segment maintenance. Once the stand-alone street segment layer has been created, the street network layer is no longer needed. The street segment layer is best viewed on the GIS map interface by displaying them alongside the original street centerline layer.

3.1.5. Other Background Reference Layers

Other spatial data layers may also be helpful as background reference. These layers typically include assessor parcel polygons and points, layers depicting the physical landscape, such as hydrological, physiographic, or land use layers, or layers of cultural features, such as schools, libraries, fire stations, and other public buildings frequently used as poll locations.

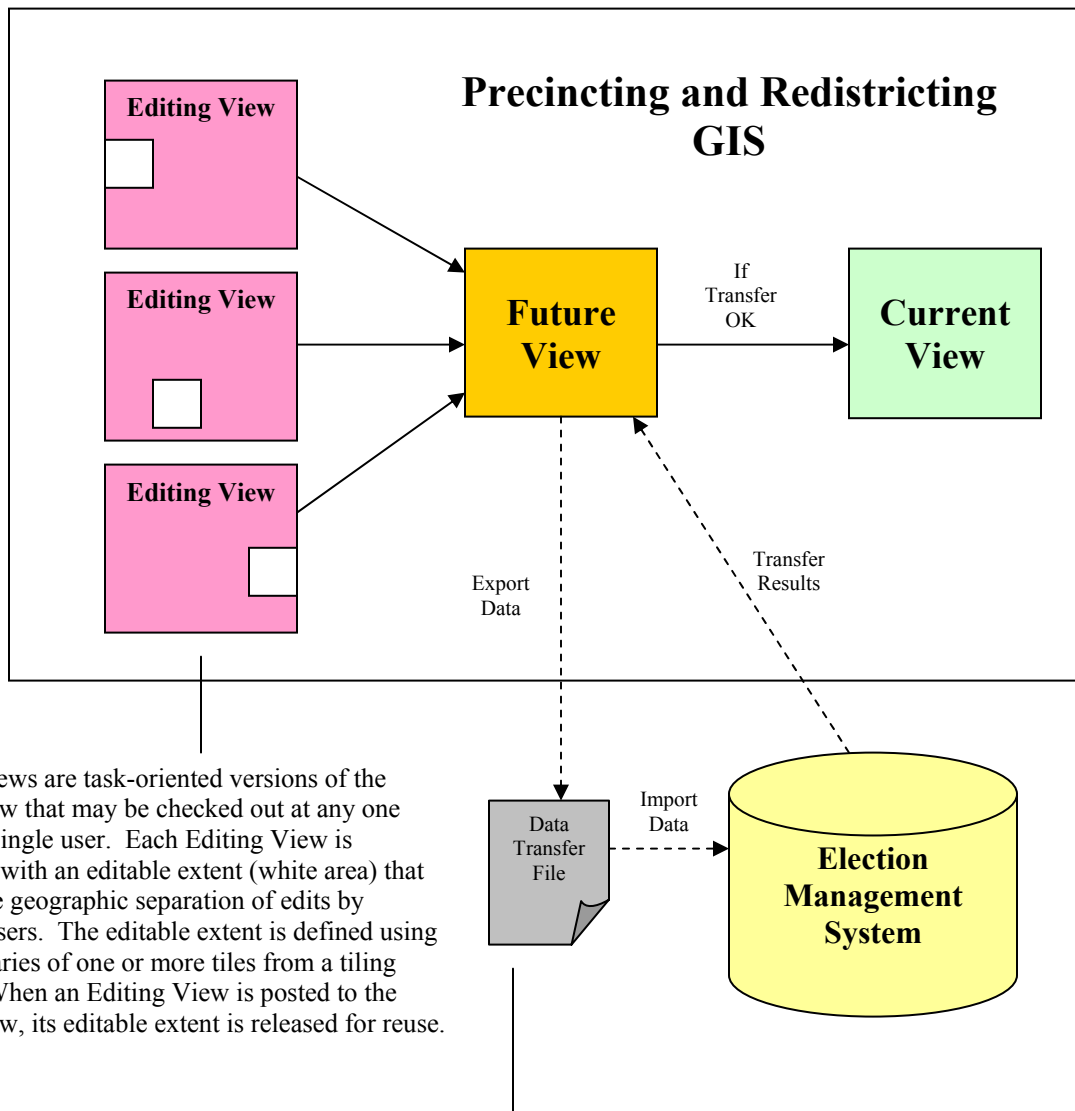
3.2. WORK FLOW AND QUALITY CONTROL

When GIS is used as a front end precincting and redistricting maintenance tool, not only is the double-entry of edits eliminated, the GIS also offers the added benefit of using the spatial analytical capabilities of GIS to maintain the relationship between precincts and street segments as both are being edited in the system, and to support data validation. As a precinct is created or deleted, or a precinct or district boundary is moved, street segments affected by the edit need to have their precinct ID attribute updated. Using a spatial query to determine which street segments are within the edited precinct, the street segments can be updated efficiently in batch mode with essentially perfect accuracy. When a street segment is moved or its shape is changed, a spatial query can determine if the street segment is moving from one precinct to another, or if it is straddling a precinct boundary, which is not allowed. If moving the street segment from one precinct to another will cause voters to be moved from one polling place to another, or if their ballot type will change, during an active election, then the street segment edit must be prevented. All of these types of data errors can be detected more efficiently using GIS spatial query capabilities.

3.2.1. Versioning

In large metropolitan areas such as Los Angeles, where thousands of precincts must be maintained over a large geographic extents, maintaining the relationship between street segments and precincts is more difficult. Prior to an election, voters are sent sample ballots and instructions that tell them what contests they can vote for, and where their polling place is. Once this information goes out to voters, no edits can be made to the precinct or street segment layers that will change a voter's ballot type or polling place. At this time, the election is said to be active and the precinct layer is frozen and cannot be unfrozen until after the results of the election have been certified. Because of the time it takes to implement many precinct changes throughout different parts of a large county precinct layer, it may not be possible to wait for an election to be certified before starting to make the precinct edits necessary for the elections the will follow. In order to support a steady flow of precinct maintenance activities, even while the precinct layer is frozen for an election, a versioning mechanism must be employed to facilitate and control the flow of edits.

Using the versioning capabilities of ESRI's ArcSDE software, RR/CC has implemented a concept of precinct layer versions called views. The Current View is the official production version of the precinct layer. All active elections are based on the Current View of the precinct layer. The Future View is a child version of the Current View. It starts out being identical to the Current View from which it derives. As precinct layer edits are made they are stored in the Future View. Once the Current View becomes unfrozen, the Future View edits can be posted to the Current View, and then they are identical again. Figure 3 below, which will be explained in the following paragraphs, introduces RR/CC's concept of views.



Editing Views are task-oriented versions of the Future View that may be checked out at any one time by a single user. Each Editing View is associated with an editable extent (white area) that ensures the geographic separation of edits by different users. The editable extent is defined using the boundaries of one or more tiles from a tiling schema. When an Editing View is posted to the Future View, its editable extent is released for reuse.

The posting of the Future View to the Current View triggers the update of the election management system database using the data transfer file, which is generated from the Future View. If any data in the transfer file fails to import and validate properly in the election management system, it sends a report of the errors back to the GIS system, and the replacement of the Current View by the Future View is aborted. If all of the data is OK, the Future View replaces the Current View.

Figure 3. Precinct Layer Editing and the Concept of Views

For Registrars of Voters of smaller counties, where only one or two staff may be needed to edit the precincts in time for the elections, the Future View may be the only other version necessary to support precinct editing. Precinct edits can be made in the GIS interface directly to the Future View version. In very large counties like Los Angeles, this is not possible. Many staff are needed to make all of the precinct edits in time for the upcoming election. To facilitate the breakdown of precinct editing tasks among the many users, and to avoid corrupting precinct geometry (which can be caused by multiple users editing the same precinct simultaneously), RR/CC utilizes child versions of the Future View, called Editing Views. Editing Views allow users to edit precincts within a certain editable extent only. The editable extent is essentially a record locking mechanism based on geographic area. When precinct edits in an Editing View are completed, they can be reviewed by the user and validated by the GIS before being posted to the Future View. In this scenario, the Future View is a storage container for edits waiting to be posted to the Current View.

Using Editing Views, however, adds some constraints to the work flow that must be taken into consideration. It can happen that the same area of the precinct layer must be edited for two upcoming tasks. To ensure that the desired precinct edits flow into the Future View, and then into the Current View, at the appropriate time, it is necessary to plan well ahead for upcoming editing tasks. This involves prioritizing them based on the amount of editing required, and when the edits must be in the Current View. Keep in mind that the number of precinct data states that can exist at any given time is limited by the number of versions that exist in the view pipeline. In the case of RR/CC, the precinct data for a particular area will have one state in the Current View, another state in the Future View, and yet another state in the Editing View. These states must be flowing in the order required to make it to the Current View to support the active election.

Finally, note that versioning is applied only to the precincts and their district assignments. The street segments do not really need to be versioned, because street segments are not subject to the same strict lockdowns during elections as precincts and district assignments (street segments can be edited as long as it does not cause voters to change their ballot group or polling place while the election is active). Also, street segments are more numerous and experience fewer edit collisions by multiple users, and since their geometry is simpler than the precincts' polygon geometry, data corruption is less likely or troublesome.

Because versioning is not required, it can be said that street segments are always edited in the Current View. However, because updates to the election management system involve exporting the Future View of the precincts, it is crucial that the street segments have an awareness of both the Current View and Future View precincts that they are in. When the Future View of the precincts is sent to the election management system, the street segments must also be sent with a reference to their Future View precincts. When street segments are sent to the election management system by themselves (as discussed below), they must be sent with a reference to the Current View precincts.

3.2.2. Topology

Many states, such as California, require that the geographic distribution of election precincts cover every part of a county, and that every part must be contained in one and only one precinct. This logical business rule can be expressed and validated in the GIS as topological rules that prohibit the precinct layer from having gaps or overlaps between precincts. In ESRI's ArcGIS, the GIS platform used by RR/CC, topological rules such as Must Not Have Gaps and Must Not Overlap can be implemented that will validate the precinct polygons against these topological rules, correct errors falling within a certain specified tolerance, and document gross errors exceeding the tolerance.

In ArcGIS, be sure to set up the precinct layer feature class and the topology within the precinct dataset before registering it as versioned. Once the precinct dataset is versioned, topology can be validated, but it cannot be deleted, changed, or created.

3.2.3. Database Synchronization and Systems Integration

The election management system at RR/CC was purchased from a commercial software vendor and, as such, operates more or less as a black box. Implementing a precincting and redistricting GIS in this environment ultimately meant that the GIS and election management system would remain distinct systems that would have to be synchronized. As illustrated in Figure 3 above, edits are made to the precincts (and to the street segments and district assignments, but this is not shown in the figure) in the GIS first. To synchronize the election management system database with the new state of precincts in the GIS, the GIS must export its precinct records to a delimited text file. This data is then imported into the election management system using tools in its user interface that read the file, validate the data, and return the import results to the GIS.

Although this process can be somewhat time-consuming depending on the number of precinct, street segment, and district assignment records (at RR/CC it takes about an hour to complete the export/import process), it is much more efficient compared to a process that involves double entry of data. Also, since there tends to be more volatility to the street segment data than to precincts or district assignments, the street segment data will frequently need to be updated in the election management system without being accompanied by precincts and district assignments. These partial updates to the election management system take less time than a full update. When street segments are exported by themselves, their precinct identifiers must reference the precincts in the Current View, not the Future View.

This method of synchronizing the databases was only feasible because the commercial software vendor agreed to customize the software functionality to allow bulk imports using a delimited text file. If the election management system that will be updated by the GIS is a proprietary software package, it will be critical to determine during the design of the GIS how it will synchronize with the external system. It may also be helpful to consider other methods of data transfer, including direct writes by the GIS to the election management system database, and using XML format instead of delimited text.

If the election management system of a Registrar of Votes was developed in-house and is capable of modification, or if a new election management system will be implemented along with the GIS, it may be desirable to design a GIS that is completely integrated into the election management system. Like RR/CC, many Registrars of Voters do not have this luxury, either because they are already committed to an existing commercial system or they do not have the available funding to create a new in-house election management system. But if the opportunity presents itself to combine GIS and election management into a single system, our experience suggests that it should be seriously considered. Election management is a geographically intensive process that stands to benefit greatly from built-in GIS capabilities, and a single system would avoid the time-consuming processes of database synchronization and maintaining two systems.

3.3. CORE FUNCTIONAL REQUIREMENTS

Conceptually, the main functional requirements of a precincting and redistricting GIS include the editing of precincts and street segments. Other support functionality is also needed, however, to ensure the integrity of the data. A list of core functionality is discussed below.

3.3.1. Precinct Editing Functionality

Following is a list of minimum required precinct editing functionality:

- Split a precinct into two precincts
- Merge two precincts into one precinct
- Perform a shared edit of the common boundaries between two adjacent precinct polygons (must not result in overlaps or gaps)
- Change the district assignments of a precinct
- Change the precinct number and other attributes of a precinct
- Validate business rules governing precincts (unique precinct number, contiguity, district assignments, etc.)
- Validate topology of precinct layer

The safest method of moving precinct boundaries is to limit edits to splitting and merging precincts, because this ensures that the resulting precinct geometry will not have gaps or overlaps between precincts. It may be possible to implement a tool for making shared edits to the common boundaries between adjacent precincts, but it is critical that this type of editing does not produce gaps or overlaps.

3.3.2. Street Segment Editing Functionality

Following is a list of minimum required street segment editing functionality:

- Edit the street segment geometry
- Edit street segment attributes (address range, street name, etc.)
- Create new street segments, or delete existing ones.
- Manage the street segment's relation to precincts

- Validate business rules governing street segments (address ranges must not overlap, zip codes correlate to postal cities, etc.)

As precinct edits flow from an Editing View, to the Future View, and finally to the Current View, it is important that the relationship between the street segment and its precinct constantly be managed and updated. This relationship is initially determined at the Editing View stage, in which precinct edits are made and the street segments are validated against these edits. When an Editing View is posted to the Future View, or when the Future View is posted to the Current View, the street segments should automatically become aware of any new precinct it has become related to.

3.3.3. Administrative Functionality

Following is a list of minimum required administrative functionality:

- Create, delete, validate and post Editing Views
- Check-in and check-out an Editing View
- Expand the editable extent of an Editing View
- Create, delete and post the Future View
- Export the Future View to the election management system
- Read the results of the import of the Future View into the election management system
- Import required data from the election management system into the GIS
- Validate the database synchronization between the GIS and the election management system

3.4. USER SKILLS AND TRAINING

The development and long term maintenance of a GIS for precincting and redistricting requires the support of staff trained in GIS technologies. This support staff should include at least one person who is both a skilled user and developer of GIS software, and knowledgeable of precincting and redistricting business procedures and rules, work flow, and data.

If business processes, work flow, or the quantity of data requires multiple users to edit the precincts and street segments simultaneously, the GIS must also include support for multi-user editing from distributed client applications that connect to a GIS-enabled RDBMS server. In addition to the support staff sited above, a client-server GIS must also include a system administrator who is knowledgeable of the RDBMS software on which the GIS database is built, and is capable of carrying out routine database maintenance, performance monitoring, and troubleshooting procedures. If a third-party software is used to spatially enable the GIS database, the system administrator must also be trained in that software. The system administrator must be able to provide technical support on the basic use of the selected GIS software.

For those Registrars of Voters that have no staff skilled in GIS technologies but are considering implementing a GIS for precincting and redistricting, it is critical to send staff to GIS training. This should be done as early as possible in the GIS implementation project, so that staff can be

utilized during system implementation on GIS data development and interface design activities. Users with GIS skills will also be able to understand better how their requirements relate to the GIS technology and can communicate them to the implementation project staff during the design of the GIS.

3.5. PROJECT PLANNING AND SCHEDULING

Because the situation of each Registrar of Voters is unique, there are numerous ways to execute a project to implement a precincting and redistricting GIS that would be successful. The following sections propose several phases that might comprise a typical implementation. It should be emphasized that this approach is only a suggestion, and should not be construed as the only way, or the correct way, to plan and schedule the project.

3.5.1. Phase 1 - Data Development, User Training, Implementation Planning

This phase will establish the basic foundations for the successful implementation of a precincting and redistricting GIS. Phase 1 will begin with a capability and needs assessment to determine what the current GIS capabilities are, and what needs to be done to prepare for the GIS implementation. If the Registrar of Voter has no GIS currently in place, there are a number of data sets that must be developed and/or acquired, and decision points that must be considered and decided before proceeding with system implementation. Users will be trained in GIS software and will participate in planning and design activities. In this phase, the precinct, street centerline, street network, and street segment GIS layers will be produced (or where possible purchased), and the system specification (including hardware/software architecture and system functionality) will be designed and delivered. Since the street segments must be validated against the precincts after they have been converted to a GIS layer, it is necessary to complete the development of the precinct layer (if necessary) before finishing the development of the street segment layer. At the end of this phase, the Registrar of Voters will have ready the data sets needed to effectively manage its precincting and districting work flows, and documentation in place to successfully execute the implementation.

3.5.2. Phase 2 – Implement Administrative Functionality

Prior to being able to edit precincts and street segments, the functionality for working with the different views of the precinct layer, synchronizing the GIS database with the election management system, and managing layer content in the GIS database and on the GIS map interface must be developed. Not only is this necessary for getting to the point where precinct and street segment data can be edited and validated on the map, it will also help to expose any potential issues with the implementation of the system. For example, it could yield valuable unforeseen issues with the versioning structure of the system or with synchronizing with the election management system. Of critical importance is being certain that, if the election management system is a separate vendor platform, the vendor will incorporate functionality for importing the data from the GIS, or giving the GIS direct access to the system.

3.5.3. Phase 3 - Implement Precinct Management Capabilities.

This phase will implement the critical aspects of the Registrar of Voter's precinct maintenance operations in the GIS, including managing precinct district assignments. At the end of this phase, the Registrar of Voters will have an in-house ability to perform visual precinct and district data validations, and make needed modifications in the GIS environment.

3.5.4. Phase 4 – Implement Street Segment Management Capabilities.

This phase will implement the functionality for managing the street segment as a GIS layer. This functionality will include tools for fixing street segment data errors and facilitating the matching of unmatched street segments to the street centerline layer. Street segments can be edited to support precincting and redistricting processes and automated data validation can be performed to better ensure correct relationships between the street segments and precincts. Street segment management functionality should not be implemented until after the precinct layer has been fully developed.

3.5.5. Phase 5 - Develop Precinct and District Mapping Capabilities

This phase will develop automated mapping tools for querying layers and tables in the precincting and redistricting GIS and generating maps of precincts and/or districts for printing in hard copy or digital format. The data in the GIS will also support the publishing of GIS data on the Internet using internet map server technology. This phase can be undertaken once Phase 2 is complete, since street segments do not contribute to generation of precinct or district maps.

3.5.6. Project Scheduling

For those Registrars of Voters interested in implementing a precincting and redistricting GIS from scratch in time for the district reapportionment following the 2010 decennial census, it is recommended that project planning begin as soon as possible. The capabilities and needs assessment may reveal that the Registrar of Voters is better prepared than originally thought, but the opposite is more likely the case. Procuring data from commercial data vendors will speed up the data development process, but it is important to understand the costs and constraints associated with purchasing or licensing data from a vendor. Developing the precinct layer, and the street centerline layer necessary for creating the street network and the street segment layers, can take a year or more to arrive at acceptable levels of accuracy and completion. Once these are in place, the functionality for maintaining the precincts and street segments must be designed and developed. RR/CC knows of no commercial software vendors who sell a COTS precincting and redistricting GIS that includes support for street segment management. Designing, developing, testing, and deploying this custom software can take another year or more. More likely, it will take several years to get the GIS to a point where it is fully debugged and enhanced, and is fully understood and being used in a capacity to facilitate precincting and redistricting operations. In total, it could take up to five years to develop a mature GIS system that can support the considerable work load that will be created by the 2010 district reapportionment.

4. CONCLUSION

The Los Angeles County Registrar-Recorder/County Clerk has been using GIS and advancing its GIS capabilities for over ten years. It has a long history of using GIS to support its election-related operations, and through its knowledge and experience has come to understand the very special needs that Registrars of Voters have for GIS, and the great potential GIS offers for automating, streamlining, and improving precincting and redistricting and other election-related operations. A precincting and redistricting GIS requires several important datasets, including a precinct layer, district tables, a street centerline layer, and a street segment layer (representing the address ranges that are typically used in election management systems to link voters to precincts). This document described the steps for developing or obtaining these datasets. It also described how versioning, topology, and database synchronization can be used to manage the work flow and quality control within the precincting and redistricting GIS and between the GIS and the election management system. The core functionality needed by the GIS for maintaining precincts, street segments, and their relationships, was enumerated, and the minimum skills requirements for GIS users and administrators were described. It was emphasized that user training in GIS should take place early in the GIS implementation, in order to involve the participation of the future users of the GIS in the data development and system design efforts. Finally, it was stressed that now is the time to start the planning the GIS implementation, if the GIS is to ready in time for the 2010 district reapportionment. From the experience of RR/CC, it could take several years to get a mature GIS in place that can support the district reapportionment work load that will be generated by the 2010 census. A high-level project plan for implementing the GIS in logical and orderly phases was proposed, although it was cautioned that the situation of each Registrar of Voters is different, and there are many approaches and schedules to a GIS implementation that would work well.