A COMPARISON OF ADDRESS POINT AND STREET GEOCODING TECHNIQUES IN A COMPUTER AIDED DISPATCH ENVIRONMENT

by

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DEDICATION

I dedicate this document to my mother, sister, and Marie Knudsen who have inspired and motivated me throughout this process. The encouragement that I received from my mother and sister (Kim and Vanna) give me the motivation to pursue this master's degree, so I can better myself. I also owe much of this success to my sweetheart and life-partner, Marie who is always available to help review my papers and offer support when I was frustrated and wanting to quit. Thank you and I love you!

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Thank you!

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LIST OF ABBREVIATIONS

AVE	Avenue
BLVD	Boulevard
BPD	Brea Police Department
CAD	Computer Aided Dispatch
CIR	Circle
CT	Court
DR	Drive
EOC	Emergency Operations Center
Esri	Environmental Systems Research Institute
GIS	Geographic Information System
IT	Information Technology
LN	Lane
LP	Loop
PKWY	Parkway
PL	Place
POI	Point of Interest
PDF	Portable Document File
RD	Road
ST	Street
TER	Terrace
TIFF	Tagged Image File Format
TRL	Trail

ABSTRACT

Understanding address points and street ranges is critical for providing information quickly and accurately to emergency responders. This thesis investigates the process of updating address points and street ranges in a computer aided dispatch (CAD) environment to help improve response time for emergency services while developing a more reliable geocoder for CAD. In a geographic information system (GIS), addresses verify through a process called geocoding, a topic that is currently being studied and tested in many CAD environments. Geocoding is one of the most critical components in CAD because Dispatchers depend on it to accurately confirm the location and relay the information to first responders. Based on the applied work experience and lessons learned in supporting CAD, an exact match to the property, or calls-for-service locations, are critical and can potentially save lives. Using street ranges for address verification is not as accurate as address points because street ranges only provide an approximation of location, which can require additional efforts to locate the caller and increases response time. Ideally, Dispatchers require each call point be provided as an exact physical location. This investigation examines the City of Brea, California as a case study on GIS administration in the capacity of maintaining and updating GIS data for CAD use. Verifying emergency call requests is one of the most important functions, allowing Dispatchers to send appropriate aid expeditiously. Therefore, accurate and current address point and street range information are critical in the performance of CAD functions. The results of the research inform the fitness of use and accuracy of address points versus street ranges in a CAD environment for the City of Brea, California. Moreover, this research aims to promote greater data sharing and interagency cooperation among local, county, and state agencies in the United States.

CHAPTER 1: INTRODUCTION

This research aims to inform the fitness of use and accuracy of address points versus street ranges in a CAD environment, and to promote greater data sharing and interagency cooperation among local, county, and state agencies. In addition, results of this research were used to validate the superiority of address points versus street ranges in the City of Brea, California CAD system. The City of Brea continues to embrace GIS technologies because its functionality is currently integral to the success and deployment of CAD. The main goal of geocoding technology for the City's CAD system is to pinpoint the locations of 911 calls as precisely as possible, resulting in faster response times.

There are various ways in which geocoding techniques are applied, such as locating and responding to 911 calls, or to the investigation on Dengue fever in many parts of Africa (Goldberg 2011). As street addresses help individuals to locate one another in this complex world (Zanbergen 2008), in GIS, geocoding, which is the process of verifying address locations, is a topic that dates back to the early 1960s when a team of researchers from the United States Census Bureau studied how to better validate, locate, and store the nation's address information (O'Reagan and Saalfeld 1987).

In a CAD environment, one of the most critical components for Dispatchers is to accurately verify the location of a property, or calls-for-service, resulting in faster emergency response time. Herein, calls-for-service refers to 911 calls initiated by the public that requires immediate response from public safety personnel for aid. In this matter, an exact match to the property is preferred. Using street ranges for address verification is not as accurate as address points. This is because street ranges provide an approximation of the location, resulting in greater effort to find exact locations and thus reduced response time. Therefore, Dispatchers prefer that each call points to the exact physical location. Additional discussions on what defines an exact or approximate match will be provided herein.

One of the significant challenges facing the GIS community is to maintain and update geospatial data for CAD. The City of Brea's CAD system, which is operated under the Police Department (PD) and supported by their in-house Information Technology Division (IT), is fully dependent on their GIS data. These data layers include address points, street ranges (or address ranges), parcel information, property lines, reporting districts, beat boundaries, city boundary, surrounding cities, fire stations, police stations, parks, schools, and retail locations. The city boundary, beat boundaries, and reporting districts do not require frequent-updates, since their spatial references seldom change. On the other hand, address points and street ranges do require monthly updates. As verifying emergency call requests is one of the most important functions of the City of Brea's CAD system, allowing Dispatchers to send appropriate aid expeditiously, accurate, current address points, and street range information are critical in the performance of CAD.

1.1 Brea, California

The City of Brea, once a small oil producing town surrounded by wildland areas in north Orange County, is now a bustling city, close to reaching its maximum building limits, based on the City's general plan studies (see Figure 1).

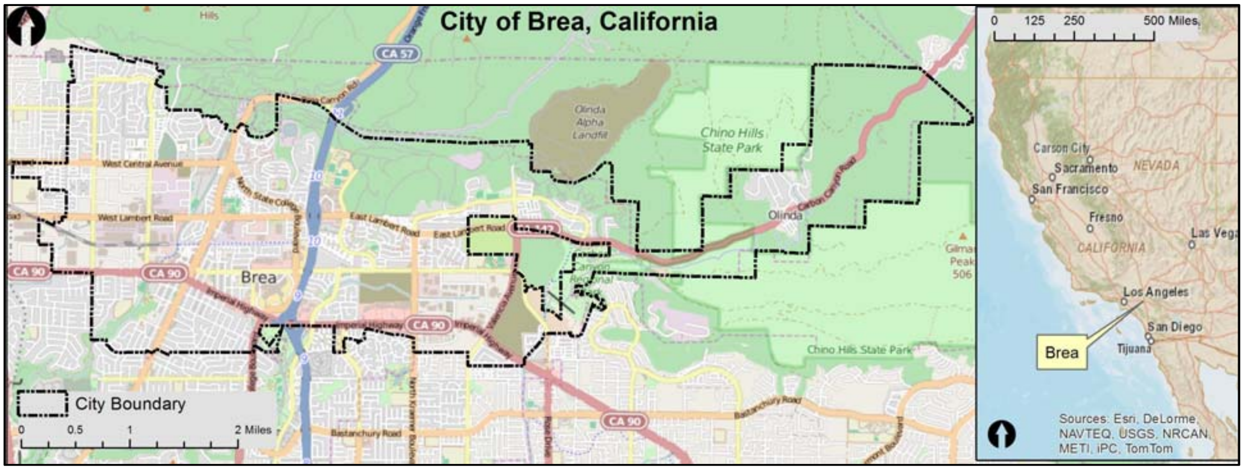


Figure 1. City Boundary Map of Brea, California

Brea is approximately 30 miles east of Los Angeles, with a population of over 42,000, and daytime population of over 100,000 that has been increasing steadily since the 1970s, with the opening of the Orange Freeway (57) and Brea Mall (City of Brea 2015). As mentioned previously, Brea has its own police department, an outstanding public school system, as well as fire services, and active commercial and residential sectors that make it one of the most desired places to live and work (Brea Olinda Unified School District 2015). As the continued growth of the City further intensifies the demand to provide public safety, the CAD system needs to geocode addresses correctly to ensure faster response times to 911 calls.

There are many benefits for an interagency CAD system, such as shared deployment costs, better management of GIS datasets, consistency, and more knowledge sharing opportunity among the GIS community. Unfortunately, at this time, similar to other agencies in Southern California, Brea's proprietary CAD system is an obstacle for sharing resources with neighboring agencies. Another motivation for this study, it was becoming more difficult for Dispatchers to verify calls-for-service locations, resulting in longer response times.

Prior to this study, common CAD issues were becoming difficult to resolve within the City's existing IT system, including: (1) problems with updating and removing existing address points, common place names, and contact information; (2) the inability to verify calls-for-service and the challenges posed by street information that was out of range; and (3) addresses did not match police reporting districts. As these issues progressed, moving to a GIS based CAD system provided dispatch the optimal tools necessary to respond to emergency calls as a means of improving public safety for Brea residents.

Over the last several decades, advancement in GIS functionality has made it an integral part of supporting any CAD systems (Babinski 2009). For example, improved location-based data access, advanced software, and hardware are providing many more opportunities in the uses of GIS technologies for supporting CAD (Newcombe 1994). In 2007, Ray Drlik, former Brea Information Technology Manager, hired the City's first full-time GIS Analyst to support city staff and their new GIS-based CAD system. In the public safety sector, GIS has been used for decades to identify, record, and respond to emergency requests (Nesbary 2001). Many emergency coordinators, Dispatchers, and first responders rely on GIS to pinpoint emergency call locations and provide appropriate responses quickly (Newcombe 1994). Today's CAD systems nationwide typically depend on GIS to identify and respond to emergency calls.

Improved alternative solutions in the management of a CAD system are more possible today due to the continued advancement in GIS software, hardware, data, and more qualified GIS professionals (Mehrotra et al 2013). Today's CAD systems have moved far beyond the Microsoft Disk Operating System (MS-DOS) base that used command lines and identified emergency service calls on a monochromatic computer screen (Mehrotra et al 2013). Current CAD systems are visually impactful, with a map-based graphical user interface that supports quick identification of the caller, their location, and response to emergency calls.

The integration of GIS and spatial data in CAD continues to grow (Dvorak 1997). In the early 2000's CAD administrators in Brea demanded a better visualization or user interface as part of their dispatch system. In 2007, the City of Brea began the process of replacing their existing CAD with a graphical user interface (GUI) and map-based system. After a lengthy selection process, Intergraph Corporation (Intergraph 2015), a premier geospatial and CAD vendor, was awarded the contract to develop Brea's next generation CAD 911 system. Moving to an Intergraph based CAD system required extensive data migration. Intergraph uses proprietary software, customized interfaces, and data formats that are different than the City's Esri based GIS infrastructure. The software and data challenges during this Intergraph data migration involved consolidating Esri's feature classes into Intergraph's data format for its CAD mapping system. Since Brea uses Esri software and data architecture, it was a challenge to migrate the City's data to work in Intergraph, and took over a year to accomplish.

1.2 Motivation

The role of local government is to serve its residents. There are many services local government provides (Babinski 2009), such as home inspections, trash services, road maintenance, building permits, business licenses, meal services for low-income seniors, and police and fire services for the community. As the demand for these services increases, particularly in public safety, cities like Brea are motivated to find better technology to facilitate services provided to their constituents. Advancement in GIS software, computer hardware, and sensor technologies make it more plausible for a local agency to be more effective in providing public safety for its citizens. Without these advances and lowered deployment costs, a GIS based CAD system would not be possible in Brea.

1.3 Research Questions and Objectives

There were two questions in this research. First, which address locator is more accurate to use in a CAD environment? Second, does this research promote greater interagency cooperation and data sharing within the GIS community who supports CAD systems nationwide?

In order to answer each of these questions, four objectives were set for this thesis. This thesis aimed to: (1) analyze over 16 thousands calls-for-service locations in Brea between January 1 to December 15, 2014; (2) geocode the calls-for-service locations and compare the accuracy rates between the Single-House Locator and Dual-Ranges Locator; (3) compare the geocoded results through field inspection to determine its proximity to the physical locations; and (4) determine the fitness of use and accuracy of address points versus street ranges in a CAD environment for the City of Brea. Several techniques were utilized in order to accomplish the study's research objectives, including relevant work experience in the administration of GIS data for CAD.

1.4 Thesis Organization

Chapter one begins with a background of current work in the maintenance of CAD within the GIS community and review of relevant research articles on the process of updating address points and address ranges for CAD.

Chapter two examines the literature reviews incorporated in this study, including an overview discussion on geocoding techniques and geospatial data accuracy of the study area, and how the GIS data was prepared.

Chapter three discusses the methodology applied in this study, including an overview of the study area, analysis of the CAD data sources utilized, and how the GIS input data was prepared. In addition, the procedure used to complete this study is explained: a comparison analysis of street ranges and address points, georeferencing techniques, address point creation, assigned common places, and project workflow in a CAD environment.

The results, Chapter four, provides an analysis of 911 call locations for the year 2014 in the City of Brea, including how the calls compared when geocoded against multiple address locators. Two address locators are included in the analysis: Single House Address Locator and Dual Street Ranges Address Locator, which produced different matched rates to assess overall accuracy.

Chapter 5, the final chapter, discusses the conclusions determined based on the results, the validity of the results, the challenges within the GIS community in managing a CAD system, and the future work to be considered.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

For some time now, geocoding has been a term only understood by individuals and organizations in disciplines such as geography and spatial sciences. At the same time, advancement in computer hardware and mapping software has been crucial in the uses of geocoding in today's globally connected world. For example, Google Maps, Apple's iPhones, and the navigational system in many vehicles use geocoding technology to provide driving directions to the nearest steakhouses or recommend alternate routes during unexpected road closures.

Moreover, GIS information is widely used in many government agencies for emergency preparedness. For example, during a natural disaster, access to pertinent information quickly can mitigate potential loss of lives and property. In the early morning of November 15, 2008, a brush fire from Corona, California, quickly spread to Brea, due to the extreme dried vegetation and changing wind conditions (Freeway Complex Fire 2013). All designated City personnel (including GIS and Dispatch) reported to the Emergency Operations Center (EOC) at Brea City Hall to assist with information gathering and logistics. As shown in Figure 2, City staff worked with county and state agencies to gather pertinent information and produce an assessment map showing the affected burn areas, size, and agencies involved in fighting the wildfire.

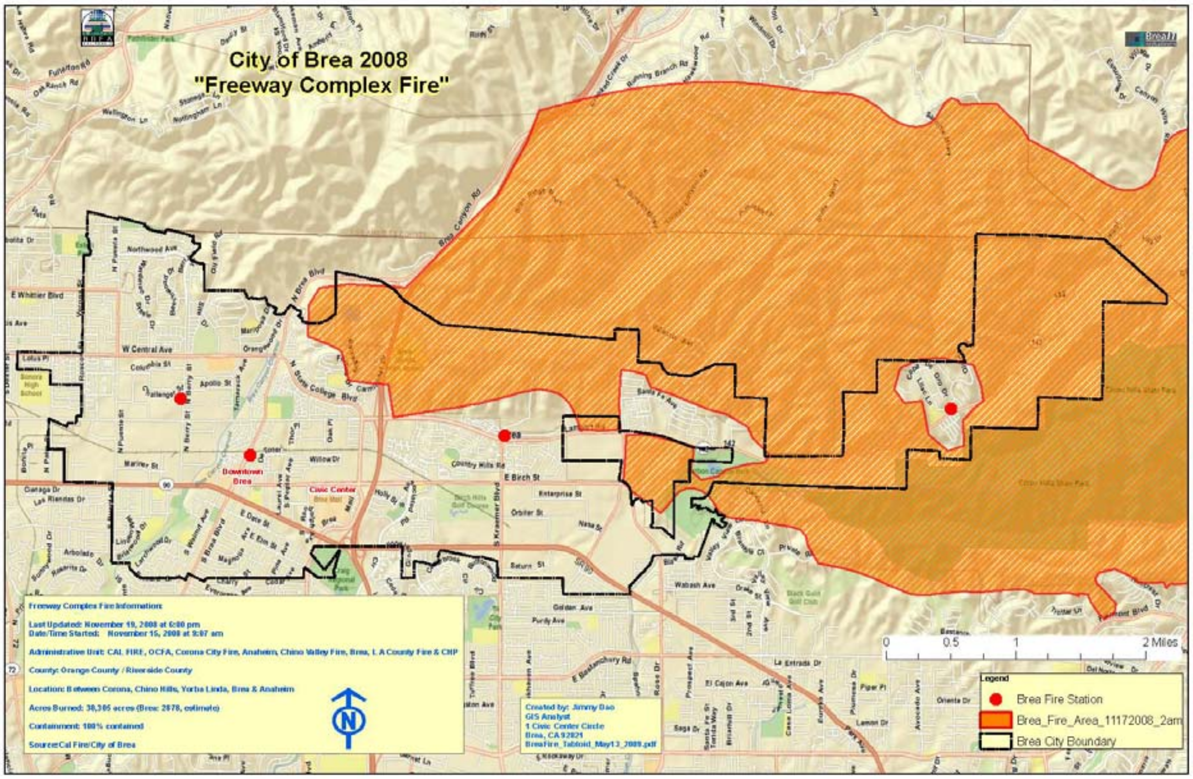
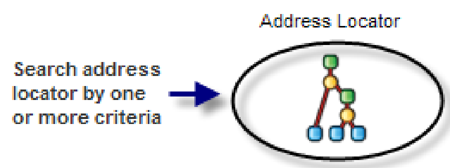


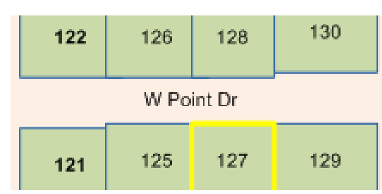
Figure 2. Freeway Complex Fire, provided by City of Brea, 2008

Using existing GIS data from the City of Brea, information provided by the Orange County Fire Authority and CAL Fire (statewide fire agency), the Freeway Complex Fire showed that interagency cooperation for emergency response is possible.

The term geocoding may represent different things to different individuals, but, in essence, it means coding the Earth with geographic reference information (or data layers) that can be reconciled for computer mapping uses (Harries 1999). The history of geocoding goes back to the early 1960s and the U.S. Census Bureau, to identify methods of mapping data collected in the field across the country, address by address (Harries 1999). For example, the major development of automating the geographic coding of postal addresses was accomplished by the Census Bureau in 1963 (O'Reagan and Saalfeld 1987), leading to the evolution of today's geocoding technology. For Brea's CAD system, the geocoding of 911 calls is supported by

Intergraph mapping software that relies on the underlying data layers (address points and street ranges) to be as accurate as possible. Today, there are numerous geocoding algorithms described in the literature and used in open source and proprietary GIS software packages. Detailed information regarding the mathematics and computational technology underlying the science of geocoding can be found in Zhan and et al (2006) article, thus is not presented in this thesis. A synopsis of this technology and the geocoding process utilized in this thesis work is provided in Figures 3 and 4 below (Esri 2014).

<table>
<tr><th>Step</th><th>Conceptual example</th></tr>
<tr><td>1. Original address entered</td><td>127 West Point Drive, Olympia, WA 98501</td></tr>
<tr><td>2. Address Parsed</td><td>127 | West | Point | Drive | Olympia | WA | 98501
127 | West Point | Drive | Olympia | WA | 98501</td></tr>
<tr><td>3. Multiple representations of the address created</td><td>
<table>
<tr><td>House number</td><td>127</td><td></td><td></td></tr>
<tr><td>Direction</td><td>west</td><td>w</td><td></td></tr>
<tr><td>Street Name</td><td>point</td><td>west point</td><td></td></tr>
<tr><td>Street type</td><td>drive</td><td>dr</td><td>drv</td></tr>
<tr><td>City</td><td>Olympia</td><td></td><td></td></tr>
<tr><td>State</td><td>wa</td><td>washington</td><td>wash</td></tr>
<tr><td>ZIP</td><td>98501</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>4. Address locator searched</td><td>


</td></tr>
<tr><td>5. Score of each potential match established</td><td>
<table>
<tr><th>Street</th><th>Number</th><th>Direction</th><th>Match Score</th></tr>
<tr><td>Point</td><td>127</td><td>W</td><td>100</td></tr>
<tr><td>Point</td><td>129</td><td>W</td><td>85</td></tr>
<tr><td>West Point</td><td>121</td><td></td><td>80</td></tr>
<tr><td>West Point</td><td>137</td><td></td><td>80</td></tr>
<tr><td>Pointe</td><td>138</td><td>W</td><td>70</td></tr>
</table>
</td></tr>
<tr><td>6. List of candidates filtered</td><td>
<table>
<tr><th>Street</th><th>Number</th><th>Direction</th><th>Match Score</th></tr>
<tr><td>Point</td><td>127</td><td>W</td><td>100</td></tr>
<tr><td>Point</td><td>124</td><td>W</td><td>85</td></tr>
</table>
</td></tr>
<tr><td>7. Best candidate matched</td><td>127 W Point Dr, Olympia, WA 98501</td></tr>
<tr><td>8. Matched feature indicated</td><td>


</td></tr>
</table>

Figure 3. Diagram of a geocoder process (Esri 2014)

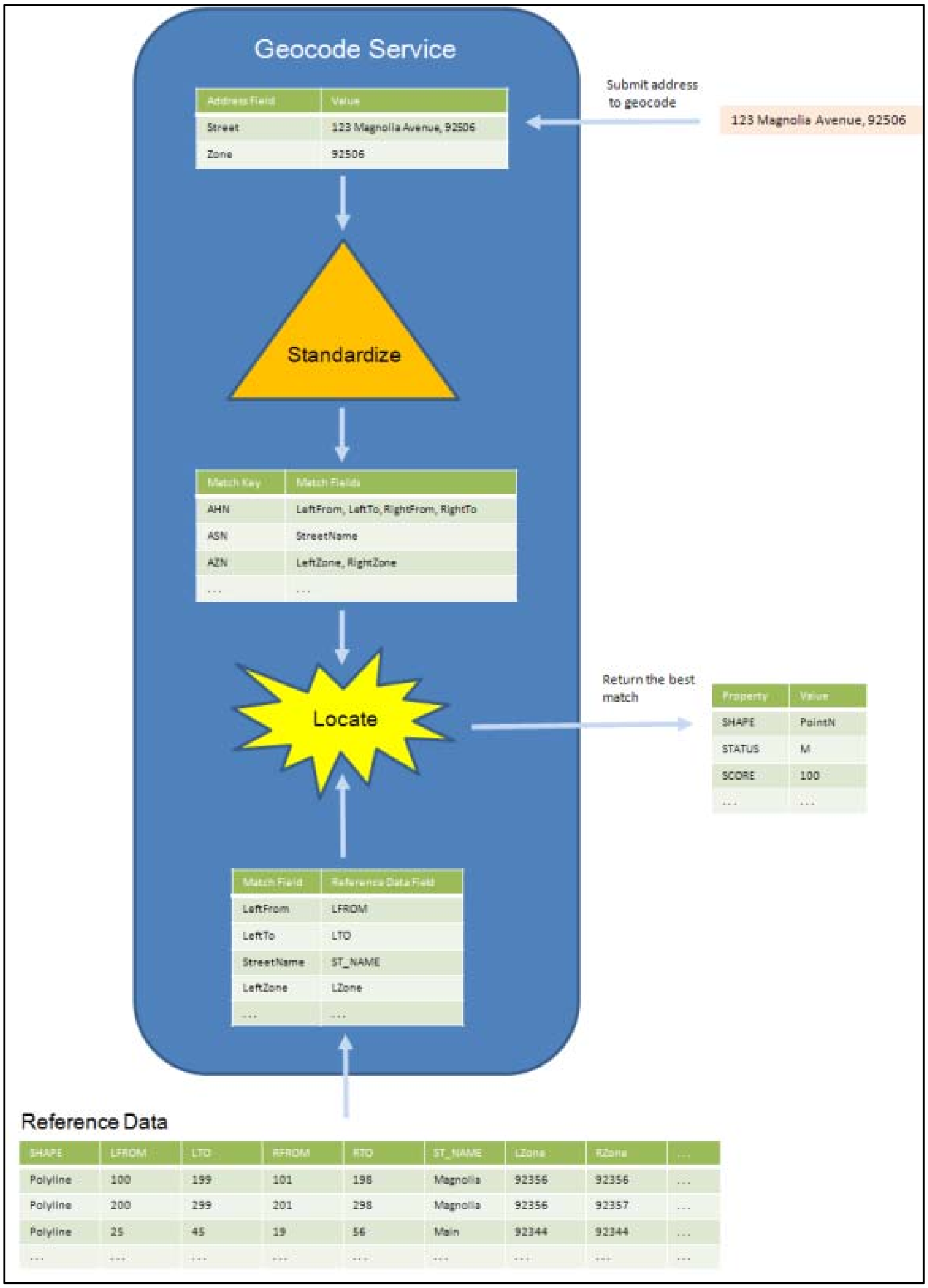


Figure 4. Diagram of a geocoding service in progress (Esri 2015)

When configured in a GIS application (desktop or web-based), a geocoder is one of the most powerful geoprocessing tools, able to quickly and accurately validate addresses. As shown in Figures 3 and 4, geocoding requires multiple processes and calculations to take contextual information (127 West Point Drive) and reconcile with the reference information to produce GIS features for uses in a computer mapping application. In addition, these diagrams offered a framework to the methodologies associated with this thesis and its findings.

The Esri ArcGIS geocoder offers different types of address locator styles which can be configured by the user. An address locator is the main tool for geocoding in Esri's ArcGIS software; it converts textual descriptions of information into geographic features (Esri 2013). On the other hand, the address locator style, is the skeleton of the address locator, it determines the types of addresses that can be geocoded, communicates with the reference dataset, and determines the output information (Esri 2013). The critical issue is that the choice of an address locator can be extremely difficult for GIS users. Structure of Esri ArcGIS software allows an in-depth comparison of address locators, which has not been previously documented in the literature.

In a GIS application (desktop or web-based), many complex spatial data layers sit on top of one another, displayed on the computer screen often in multiple colors and symbols intended to present a full picture of the overall subject matter. GIS maps can display complex information in a way that is simple to understand. A geocoder can be a GIS user's best friend, helping to retrieve location information quickly.

For instance, the Topologically Integrated Geographic Encoding and Referencing (TIGER) data, developed by the U.S. Census Bureau, is an example of a reference dataset used to geocode addresses nationwide (Klosterman and Lew 1992). The TIGER file is a polyline based file, with address ranges tied to each polyline or street segment as shown in Figure 5.

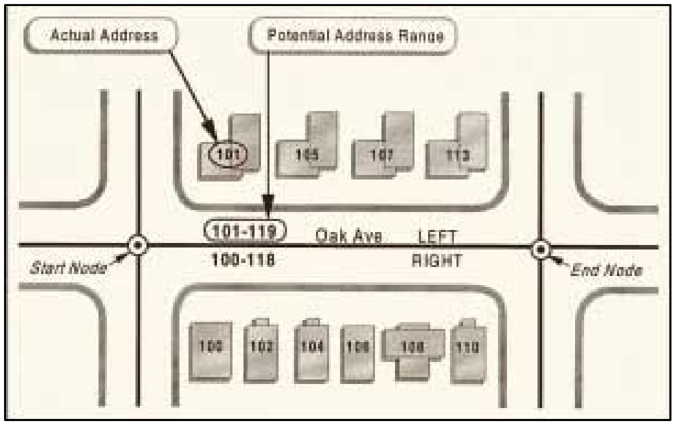


Figure 5. Map showing TIGER/Line segments and address ranges (U.S. Census 1997)

Each street segment, or line, has low and high values at the line's endpoint, such as 200 and 299 S Brea Blvd (Kellison 2012). In this case, 250 S Brea Blvd would be assigned by the geocoder to the middle of the street segment.

Conversely, a failed geocoding result will occur if an address is entered outside of the given street range provided in the reference dataset, because the geocoder only recognizes textual information that is within its given range. Therefore, the success of a GIS application requires that the reference dataset, like the TIGER data, be fully vetted to assure that it successfully searches for addresses. Depending on the data quality, each street segment should include attribute fields that are used to identify the street name, street type, directional prefix, suffix, and address ranges. In a street range geocoder, the geocoded information, based on the reference dataset, is often an estimation of the physical location (Davis Jr. and Fonseca 2007). On the other hand, in an address point-based locator, each result should be matched exactly to the reference data (Brosowsky and Ekdahl 2012). For a consistent geocoder, frequent updates to the address range dataset is mandatory. In addition, the user also needs to provide the information accurately, such as filling in the address completely (i.e. "140 S Brea Blvd, Brea, CA, 92821"), without grammatical errors, correct spelling of street name, abbreviation of a street type, and avoid formatting errors (Yildirim et al. 2013).

Goldberg and Cockburn (2010) developed a best-match criterion to describe the choices used by a geocoder to determine the best output from a set of candidate results. The methodology includes several approaches to enhance the efficiency of a geocoder. They devised a hierarchy-based approach where reference datasets are placed into a qualitative and arbitrary ranking and the address locator listed first will be used first. This method assumes relative accuracy between the reference layers. Another is an uncertainty-based approach where the reference data sources are first sorted from low to high based on their position within the hierarchy.

2.1 Data Accuracy

Great strides have been developed in the last twenty years to improve the accuracy of digitized data in GIS to facilitate applications like CAD, because data accuracy is critically important for the myriad of uses of GIS data. In the case of geocodes, the more accurate the results, the more lives can be saved.

Accuracy in a digitization environment is affected by the characterization of positional error, where the error is contributed by the operator or media type (Bolstad et al 1990). Bolstad and et al (1990) examined the findings of manually-digitized point data sampled by four operators from Mylar to paper maps. The methodology used in the study included sample location points from United States Geological Survey (USGS) 1:24,000 scale maps. USGS maps were commonly used as reference maps for creating and digitizing GIS data types like points, lines, and polygons. Bolstad and et al (1990) also discussed the concepts of accuracy and precision as useful in explaining the positional irregularity of GIS coordinate data. Bolstad (1990) sees accuracy as a measurement of the nearness of quantities to their true value, and precision measures the degree of conformity of measurements among themselves. For instance, in GIS, digital data accuracy can be reflected in errors on the map attribute database and variation of errors that are related to the reference datasets.

Another important method for evaluating accuracy and precision of digital map data includes the comparison of field survey data and coordinates derived from a GIS data layer. However, when converting paper maps to digital data, some map sources contain errors that were derived from the original paper maps. If map features were not correctly mitigated the errors may be transferred to the digital dataset. The process of collecting GIS data, whether in the field or over the internet requires advanced and careful planning. To convert analog to digital map data includes manual input of vector data, hands-on digitizing, topographic maps or high-resolution aerial imagery. For data collection and improved accuracy, manual digitization is still a common form of collecting spatial data to convert paper maps to vector layers in GIS or other types of environmental and engineering design software. In past decades, preparation for collecting manually-digitized GIS data entailed setting up map sheets to a flat table surface. A digitizing board and cursor store reference points on an analog map and transfers the control points to a workstation. As a result, systemic errors from the operator or hardware can cause degradation to the digitized data and uncertainty associated with manual digitization is small compared to other sources within this study (Bolstad et al. 1990).

GIS data collection techniques have come a long way in the last twenty years. Vast improvements in collecting control points for digitizing improve the data accuracy. In addition, with the right software and data sources, today's methods of digitizing data are vastly more efficient than twenty years ago. A digitizing board is no longer necessary to capture control points. Today, GIS software can be used to easily import images in many digital formats from scanned paper maps. Digitizing is still considered "manual" when GIS-based drawing tools are used to trace features from georeferenced images by hand using a mouse. For instance, ArcGIS desktop software from Esri allows users to create control points and digitize plan maps without the need of sophisticated tools and hardware (Esri 2013). In addition, today there are many high accuracy digital base maps, including topography, satellite imagery, and high-resolution orthophotography (3-inch aerial imagery), available to be integrated within a GIS that can be used to improve the collection of control points and manually digitized data layers. Access to high resolution imagery data from the private and public sectors have vastly improved data collection techniques in today's GIS. Nevertheless, common digitization errors that can affect the accuracy of the resulting data include digitizing data at the wrong scale and again not mitigating errors on the original maps, transferring them to the digital version.

Although there are many geocoders available, Esri geocoding tools provide the most consistent and accurate methods in the comparisons of address points versus street ranges for the City of Brea, because the City's GIS infrastructure (datasets and software) is based on Esri's file types. Data accuracy is important in this study because it affects response times. The more time that it takes Dispatchers to verify, or geocode 911 calls, the longer it takes for emergency service personnel to respond. Therefore, ongoing updates improve the accuracy of Brea's GIS datasets. The City's collection and update techniques include manual digitization of paper maps that are georeferenced and incorporated into existing data references, such as streets, parcels, city boundaries, and 3-inch aerial imagery. In the next chapter the methodology for testing the hypothesis stated in Chapter 1 will be implemented using the Esri geocoding styles: Single House Address Locator and Dual Ranges Locator.

CHAPTER 3: METHODOLOGY

Address points-based locator is the most appropriate for geocoding calls-for-service locations in a CAD environment. This study utilizes research techniques and skillsets developed through more than a decade of professional work experience within the public sector. CAD is a consistent work-in-progress system, requiring the cooperation between Dispatch and GIS personnel working together to resolve geocoding issues. When a 911 call fails to geocode from the address points-based locator, the CAD system then uses the street ranges locator to geocode the location. Development of a secondary geocoder provides Dispatch a temporary resolution to verify 911 calls. 911 call locations that were not successfully geocoded from the address points-based locator are evaluated and added to the data reference to be updated to the CAD system.

The research for this study included field work and data collection of addresses. Common place names and new street names were incorporated into the input address dataset. In addition, non-physical research techniques include digitizing and georeferencing building plans of new developments. The methodology (Figure 6) used in this thesis is to compare and evaluate the accuracy of a single house address locator versus a dual ranges address locator, using the following steps: (1) identify an address point locator style to reference with the address point feature class; (2) identify the dual ranges street locator style and assign a reference street layer; (3) assign both address locators with similar geocoding options, such as spelling sensitivity and matched rate criteria; (4) assign address table to be geocoded by both address locators; (5) review the geocoded results and overall matched rates from both locators; (6) create a visual inspection of the geocode address points using ArcMap and measuring its physical accuracy; and (7) assign ground-truthing methodologies through testing from the CAD conversion process and confirmation from Dispatch.

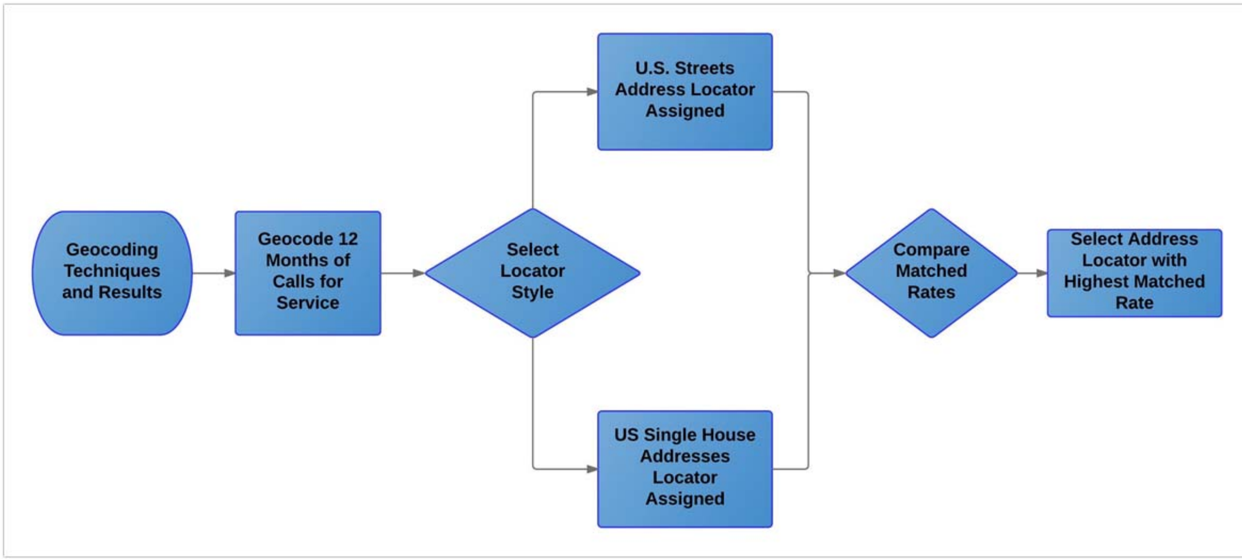


Figure 6. Project Workflow Diagram

3.1 Data Analysis

Since most government agencies today have access to GIS technologies, a GIS based CAD system is more feasible (Chatterton 1987). At the same time, each city in the United States incorporates GIS differently. In some cities, GIS serves a critical need to city functions, fully supported by a team of trained GIS professionals. For other cities, GIS is minimally utilized, usually due to a lack of awareness, untrained staff, and limited infrastructure resources.

Today, the base of building a successful CAD system rests on access to reliable GIS data, free of topology errors, such as overlapping segments and slivers. Prior to the data migration to Intergraph, a full data assessment of the City of Brea's GIS revealed that significant data cleaning efforts were needed. Fourteen critical feature layers from the City's GIS inventory, including address points and streets/centerlines layers, were insufficient in regards to topological errors, overlapping segments, missing attribute fields, and required a complete overhaul. For CAD to work correctly, the address point and street layers must accurately verify emergency calls. Additional GIS layers, such as the city boundary, parcels, police reporting districts/emergency service zones, police beat areas, and surrounding cities were reviewed to see if additional revisions were required for these to be effective CAD supporting data layers. More layers were added later, such as evacuation centers, parks, schools, shopping centers, city facilities, and hazard areas to create a richer map experience.

The data migration to an Intergraph based CAD system in Brea uncovered many challenges. Early in the data assessment, the existing city GIS data required significant revisions, or cleaning. Cleaning tasks included fixing geometry errors in the streets layer, removing slivers from the police reporting districts, updating the police beat boundaries, and adding attribute information to the address point layer. Updated parcels, address points, streets/centerlines, and reporting districts were identified as critical operational layers. Organizing and cleaning the data layers helped to successfully migrate the City's CAD to Intergraph, completed in 2008. Since 2008, Brea staff has taken over the responsibilities for supporting CAD, including ongoing software and GIS data updates to facilitate Dispatch's needs.

3.2 Street Ranges

The process for reviewing street segments for conversion to the CAD system updates is further illustrated in Figure 7, showing the complexity and efforts required during each update process.

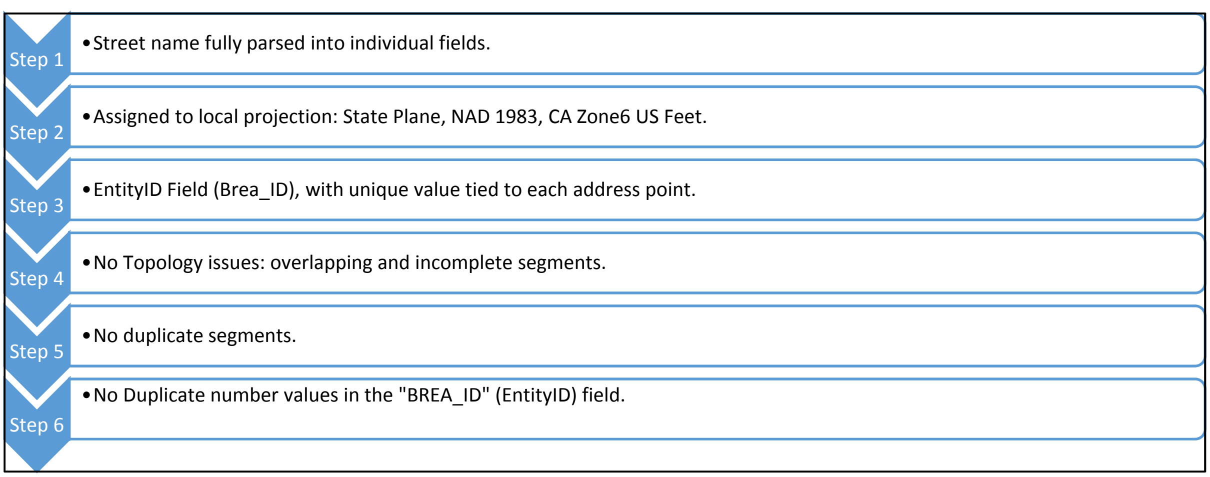


Figure 7. Street Layer Review Process for CAD Conversion

In addition, the data layers mentioned in the previous section are provided by the City of Brea and will be used to develop a workflow model in building an Intergraph based CAD system.

In the City of Brea, a streets/centerline layer that provides accurate coverage for the area that the Brea Dispatch is responsible for was critical to the success of the system. At the time, Brea provided police and dispatch services to the residents of Brea and Yorba Linda, California (neighboring city). The existing street layer did not provide sufficient attribute information to meet the demand by Dispatch. As such, the City purchased a new street/centerline dataset from Tele Atlas, a geospatial company that provides routing information for GIS applications (desktop, web-based) and other navigational devices, and was acquired by TomTom in 2007 (Hoef and Kanner 2007). The Tele Atlas street dataset included updated address ranges and routing information, single and dual-line street segments for Brea and the surrounding cities (TomTom 2015). The street layer has fields to identify speed limits, one way streets, address ranges, overpasses, underpasses, and freeway ramps, detailed in Table 1. This street/centerline layer gives CAD the capability to track, identify, respond to emergency calls, and send the appropriate help more effectively than the City's legacy system.

Table 1. Brea Street/Centerline Field Definition Table from ArcMap

FIELD NAME	DESCRIPTION
BREA_ID	Unique record number for each street segment/feature
L_F_ADD	Left from address
L_T_ADD	Left to address
R_F_ADD	Right from address
R_T_ADD	Right to address
PREFIX	Street prefix
NAME	Street name
TYPE	Street type
SUFFIX	Feature direction suffix
FCC	Feature Class Code
POSTAL_L	Postal code (ZIP or FSA) left

FIELD NAME	DESCRIPTION
POSTAL_R	Postal code (ZIP or FSA) right
ACC	Arterial Classification Code
NAME_TYPE	“R” (always PRN for this product)
SHIELD	Shield (“I,” “U,” “S,” “T,” “A” or blank) and shield subtype
HWY_NUM	#, # with letter, or blank
SEG_LEN	Segment length in miles
SPEED	Speed in miles per hour
ONE_WAY	One-way indicator
F_ZLEV	From node elevation
T_ZLEV	To node elevation
FIELD NAME	DESCRIPTION
FT_COST	From-To Impedance in minutes
TF_COST	To-From Impedance in minutes
FT_DIR	From_To Direction
TF_DIR	To_From Direction
NAME_FLAG	Name metadata flag
STATUS	Street category
FULL_NAME	Combined address fields (PREFIX, NAME, TYPE, SUFFIX)
ALIAS1_NAM	Street name alias 1
ALIAS2_NAM	Street name alias 2
ALIAS3_NAM	Street name alias 3
ALIAS1_PRE	Street prefix alias 1
ALIAS2_PRE	Street prefix alias 2
ALIAS3_PRE	Street prefix alias 3
ALIAS1_TYP	Street type alias 1
ALIAS2_TYP	Street type alias 2
ALIAS3_TYP	Street type alias 3
ALIAS1_SUF	Street feature direction suffix alias 1
ALIAS2_SUF	Street feature direction suffix alias 2
ALIAS3_SUF	Street feature direction suffix alias 3

3.3 Georeferencing

Georeferencing is a technique used to geoenable images without spatial metadata so that the information on the images can be transferred from the rasters to new vector data through digitizing, such as tracing building plans as points, lines, and polygons. The process of incorporating georeferencing for updating new streets and address information in Brea is further illustrated in Figures 8 to 11. When a new development is approved, the Building Division emails city staff, including Dispatch and the GIS Administrator of the changes. The email includes information on new addresses, street information, and an attached portable document file (PDF) of scanned plan(s) of the area. The GIS Administrator then converts the attached scanned plans to a tagged image file format (TIFF). The TIFF map file then gets added into ArcMap and overlays existing layers such as streets, parcels (if available), and imagery as reference layers for georeferencing. Georeferencing includes adding control points obtained from the TIFF map file and linking these points to the spatial georeferenced GIS layer(s). Then the digitized address points and street information are added to the existing reference layers.

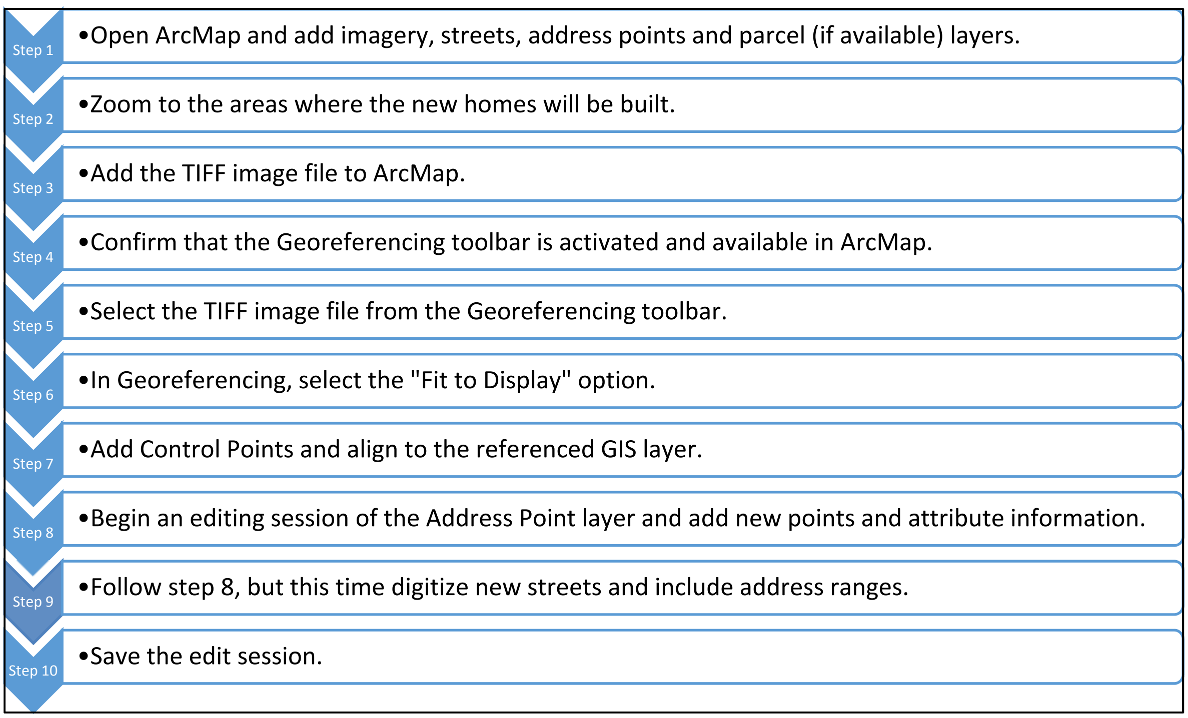


Figure 8. Georeferencing Procedures for Digitizing Address Points and Street Layers

Figure 9. Proposed New Subdivision, Using Brea 3” Aerial Imagery

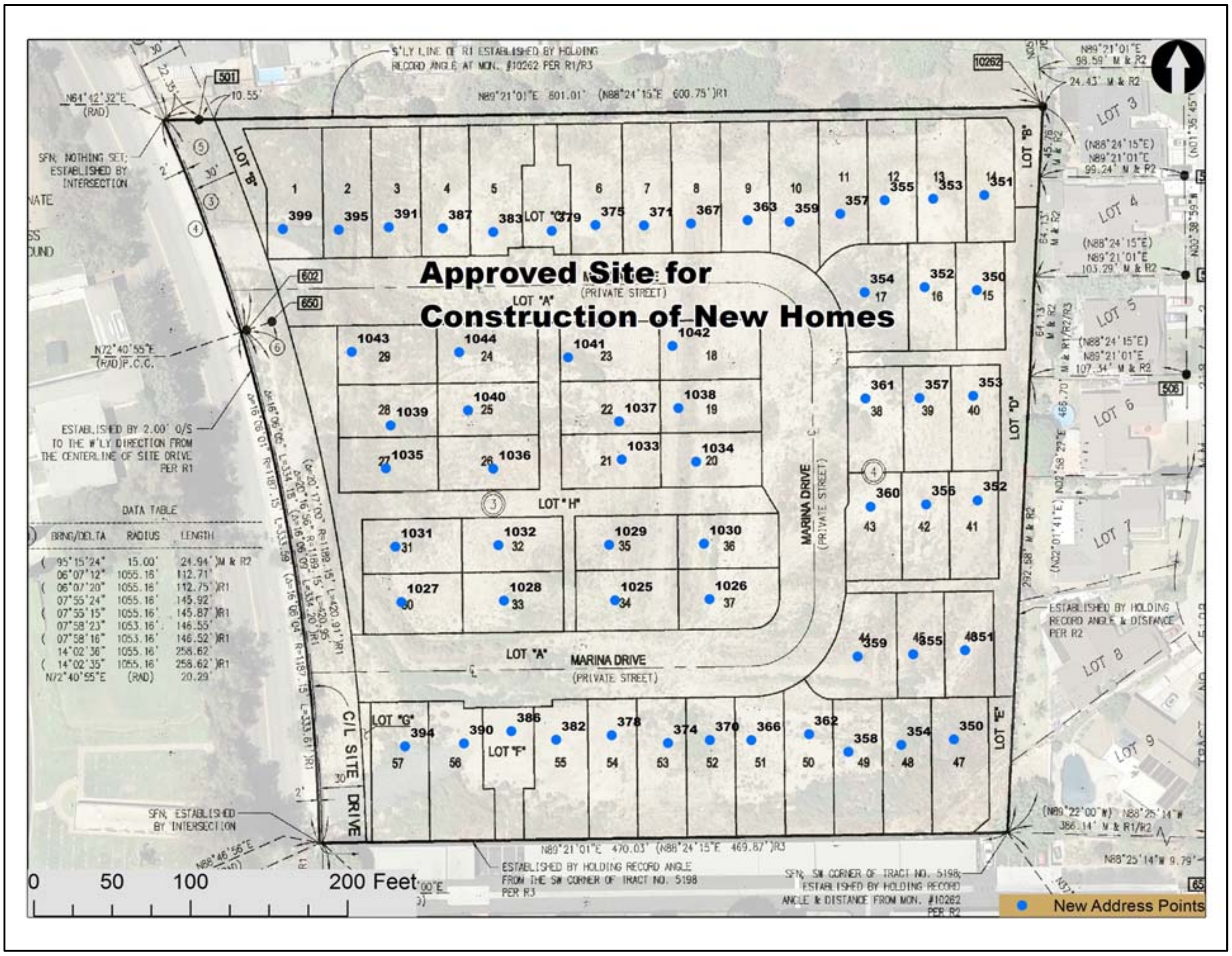


Figure 10. Georeferenced Building Plan of New Subdivision

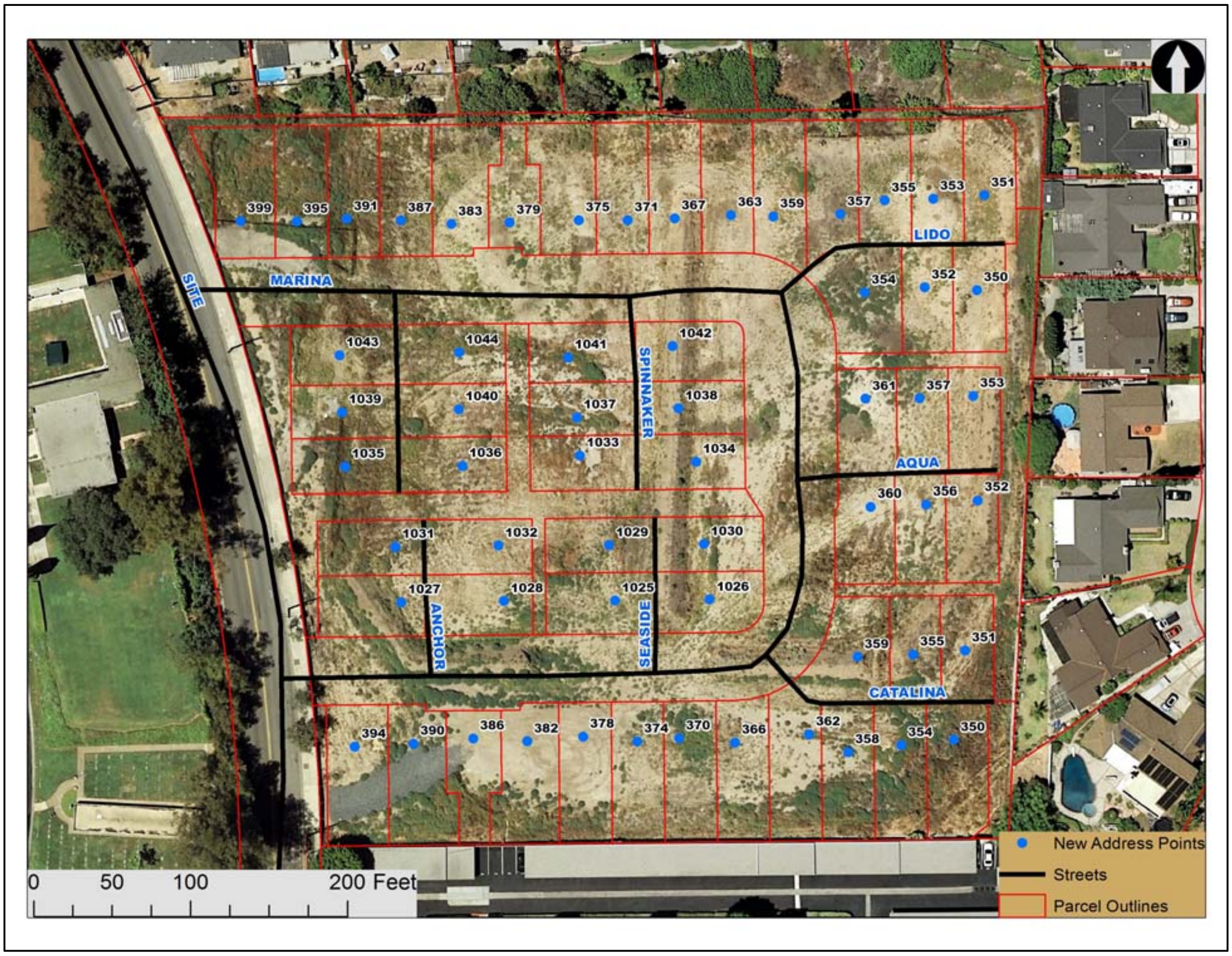


Figure 11. Digitized results of the New Subdivision

For Dispatch, address points are the preferred data reference for geocoding calls-for-service. However, when a 911 call fails to geocode from the address point layer, the CAD system mitigated that problem by using the streets/centerlines as a secondary reference data layer. The street layer provides Dispatchers the flexibility to geocode emergency calls when CAD is unable to verify from the address points dataset. Therefore, a consistent update to the street layer is vitally important. However, further discussion in this document will show that address ranges alone are not sufficient to produce the most accurate address verification (Zandbergen 2008) within a CAD environment. To better geocode 911 calls, an accurate address point layer is required.

3.4 Address Points

The address points will be updated as new construction and address change requests are made. Unlike verifying a location by the street layer or address ranges, address points provide the geocoding application (desktop or web-based) a reference to search for the exact location, without estimating where the call is coming from. When the geocoding application fails to verify a call location from the address point reference layer, the address ranges will assume the responsibility to geocode the location. With address points, Dispatch can create common places to search for locations without typing the full address. For example, if a dispatcher received a distress call for medical aid at a McDonald’s on the corner of Imperial Highway and Laurel Avenue in Brea, the dispatcher can type the business name (or one of the alias names) which can be used to facilitate determining the location, which can save valuable time in sending help (Couret 1999). Combined, both streets and address point layers work extremely well in CAD to geocode calls-for-service locations.

As Brea continues to grow, more housing and services are needed. New streets, homes, business locations, and change of businesses need to be regularly added or revised. CAD is a “work-in-progress” system that requires continuous changes and updates. Therefore, using ArcGIS’s ModelBuillder and georeferencing techniques can be used to build workflows that can help streamline the process of updating address points and street ranges.

3.5 Address Points Creation

Since Brea did not have its own address point layer, this provided an opportunity for the City to create one using the countywide parcel layer from the Orange County Assessor Office. Using ArcMap and the geoprocessing tool, the ownership property information table was joined to the parcel layer, to be later converted into an address point feature. For a simplified address point table, the attribute information from the joined parcel layer was truncated, as illustrated in Figure 12. The revised table now includes site address information, such as house number, pre-direction, street name, street type, street suffix, and unit number. See Table 2 for field descriptions of the address point table attribute.

Step 1
- Download Parcel and property information data from Orange County Assessor.

Step 2
- Add downloaded data to ArcMap for further analysis.

Step 3
- Join Parcel and property data using APN fields.

Step 4
- Export the joined parcel layer to a new feature class.

Step 5
- Add the joined Parcel layer (w/property ownership information) back to ArcMap.

Step 6
- Convert polygon parcel layer to address points.

Step 7
- Use the Feature to Point (Data Management) tool.

Step 8
- Add the new Address Point layer to ArcMap.

Step 9
- Add Brea city boundary layer to ArcMap.

Step 10
- Use the Selection Tool to select only the address points within the city boundary.

Step 11
- Export the selected address points (within city boundary) as a new layer.

Step 12
- Add new address point to ArcMap.

Step 13
- Identify address points without site address information for further research, including field work.

Step 14
- Add new fields to address points layer, based on approved specs per Intergraph.

Step 15
- ADDRESS, HOUSENUM, ADDR_PD, ADDR_SN, ADDR_ST, UNIT, SUFFIX, CITY, STATE, POSTAL, NAME, BREA_ID, LON, LAT, ALIAS1, ALIAS2, ALIAS3, ALIAS4, ALIAS5 GROUP, TELEPHONE.

Step 16
- Use "Calculate" tool to populate attribute information for the above fields.

Step 17
- Remove the joined fields and duplicates.

Step 18
- Use a number sequencing script to populate BREAID field with unique values to each record.

Step 19
- If necessary, populate NAME, ALIAS(S), GROUP and TELEPHONE field with relevant information per dispatch's requests.

Step 20
- Use the "Calculate Geometry" tool to update LAT and LON fields with local projected coordinates (NAD_1983_StatePlane_California_VI_FIPS_0406_Feet).

Step 21
- Save revised address point layer!

Figure 12. Workflow Process for Address Points Creation to Support Brea's CAD System

Table 2. Brea Address Point Attribute Table and Field Definitions

FIELD NAME	DESCRIPTION
HOUSENUM	Address number
ADDR_PD	Prefix direction for the address
ADDR_SN	Street name for the address
ADDR_ST	Street type for the address
SUFFIX	Street suffix direction
UNIT	Unit or suite designator
CITY	City in which the address is located
STATE	State in which the address is located
POSTAL	Zip Code in which the address is located
NAME	Common place name (Starbucks)
ADDRESS	Combined address fields (HOUSENUM, ADDR_PD, ADDR_SN, ADDR_ST and UNIT)
BREA_ID	Unique identification number for the address
LON	Longitude coordinate position for the address
LAT	Latitude coordinate position for the address
ALIAS1	First alias name for the address
ALIAS2	Second alias name for the address
ALIAS3	Third alias name for the address
ALIAS4	Fourth alias name for the address
ALIAS5	Fifth alias name for the address
GROUP	Group of category assigned to the address (Retail, Bank, Market)
TELEPHONE	Contact information tied to each address

Next, the truncated parcel data is exported to a new feature class. This new parcel feature class will be converted from a polygon to address points based feature class. The conversion of the parcel polygon layer involves using the Feature to Point (Data Management) tool in ArcGIS. In ArcMap, the new address point gets “clipped” to eliminate features outside of the City limits. This process uses the City boundary as a reference layer, using the ArcMap Selection tool (or the Clipped geoprocessing tool). The address point layer required specific fields and data formats. New fields including house number, pre-direction, street name, street type, street suffix, unit number, common places, aliases, telephone, and unique identification number (now known as

Brea_ID) were then added to the attribute table. The fields were populated using the “Calculate” tool in ArcMap. Prior to adding the address points to CAD, three additional quality control steps were required: (1) manual checking of the data table to confirm that each point has a fully qualified address, unit information, common place names, and contact information, with no null values; (2) each point must include latitude and longitude coordinates, based on the local defined projection, State Place, NAD 1983, CA Zone 6, US Feet; and (3) each address point must have a unique ID number in the “BREA_ID” field, this field cannot contain any duplicate values.

3.5 Common Places

The City’s CAD system is an ever evolving desktop mapping application requiring frequent updates to the address point and street layers. These updates are important for Dispatchers to better verify and geocode calls-for-service locations. The process for updating common places is illustrated in Figure 13, namely the steps to update existing address points, common places, and street ranges without georeferncing.

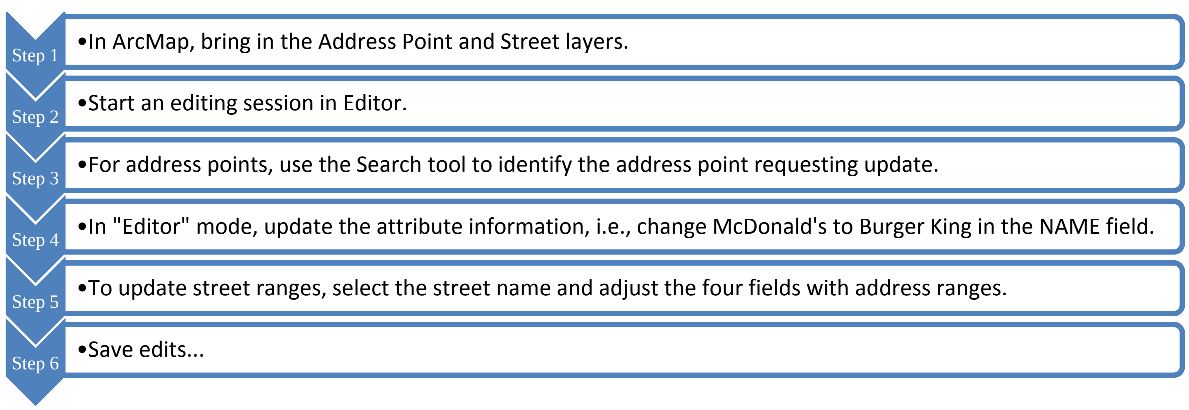


Figure 13. Create Common Places for CAD System

For example, updating an existing common place name from McDonald’s to Burger King involved identifying the feature and updating its attribute information in ArcMap. Several checks currently exist for updating address points and streets. These include adjusting street ranges, updating contact information to existing address points, or removing features.

CHAPTER 4: RESULTS

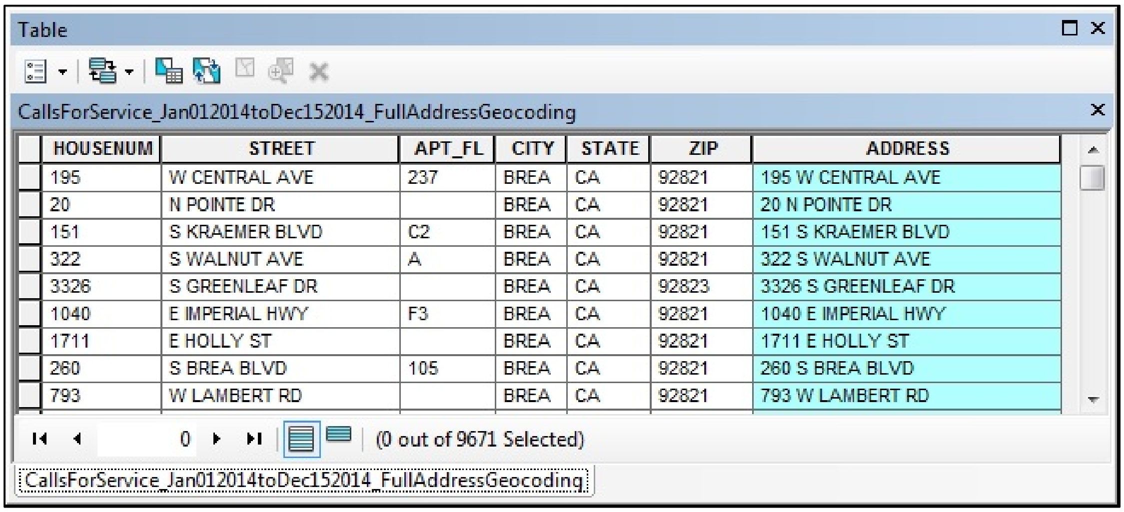
This chapter documents the comparisons of address points and street ranges in a computer aided dispatch environment. The analysis results from the geocoding matched rates show that there are advantages and disadvantages of using address points versus street layer for verifying or geocoding calls-for-service.

4.1 Calls-for-Service

As of February 18, 2015, the City of Brea has a population of 42,393 (City of Brea 2015). The Brea Police Department received 16,383 calls-for-service from January 01, 2014 to December 15, 2014 (City of Brea 2014). Calls-for-service are 911 calls that have been received by the Brea Dispatch, including emergency calls from outside city limits, due to the City's mutual aid agreement with neighboring agencies. Using the "Select by Attributes" query tool in ArcMap 10.2.2 and visual inspection, it was determined that 15,268 out of 16,383 calls-for-service originated in Brea. After further analysis and review, 9,671 calls-for-service have been identified with a fully qualified address (e.g. 1717 E Birch St) for geocoding comparisons. These 9,671 records were then geocoded against multiple address locators, such as Esri's US Address—Single House and Dual Ranges locators, in order to compare the levels of accuracies of each address locator.

4.2 Geocoding

A geocoding service, sometimes referred to as a geocoder, is a geoprocessing tool that provides a better user experience within a map application, desktop, or web-based. A geocoding service is a location, or address finder that can be used by multiple mapping technology companies, including Esri. Google Maps and Microsoft's Bing Maps would be irrelevant without a dependable, accurate geocoding service to help users find what they are looking for. A geocoding service uses customized algorithmic formulas, or a geocoding engine to display address results from a set of reference feature datasets (Zanbergen 2008). Not every geocoding service is the same, and each service requires a different data reference. For this research, two address locators and two separate reference layers were used to geocode against a table of addresses (Figure 14) to determine the strengths and weaknesses of each address locator. This process was performed using Esri's ArcGIS 10.2.2, ArcCatalog, ArcMap, and Microsoft Excel 2012.



HOUSENUM	STREET	APT_FL	CITY	STATE	ZIP	ADDRESS
195	W CENTRAL AVE	237	BREA	CA	92821	195 W CENTRAL AVE
20	N POINTE DR		BREA	CA	92821	20 N POINTE DR
151	S KRAEMER BLVD	C2	BREA	CA	92821	151 S KRAEMER BLVD
322	S WALNUT AVE	A	BREA	CA	92821	322 S WALNUT AVE
3326	S GREENLEAF DR		BREA	CA	92823	3326 S GREENLEAF DR
1040	E IMPERIAL HWY	F3	BREA	CA	92821	1040 E IMPERIAL HWY
1711	E HOLLY ST		BREA	CA	92821	1711 E HOLLY ST
260	S BREA BLVD	105	BREA	CA	92821	260 S BREA BLVD
793	W LAMBERT RD		BREA	CA	92821	793 W LAMBERT RD

Figure 14. Revised Address Table for Geocoding

4.3 Single House Locator

The Esri's US Address—Single House (herein referred to as Single House) locator style creates address locators for United States addresses (Esri 2014). This locator uses an address point feature class with over 53,000 points maintained to support Brea's CAD system. The City's address point layer represents a feature point in the reference data that corresponds to a single fully qualified or verified address from the address table (see Figure 15). In this case, each address that is being geocoded must be represented within the reference data layer; otherwise the result is an unmatched address. This style of locator does not accept a range of addresses to verify; rather it provides an exact one-to-one match criteria. Therefore, the Single House address locator style requires that each feature in the reference data correspond to a single address value, such as address points.

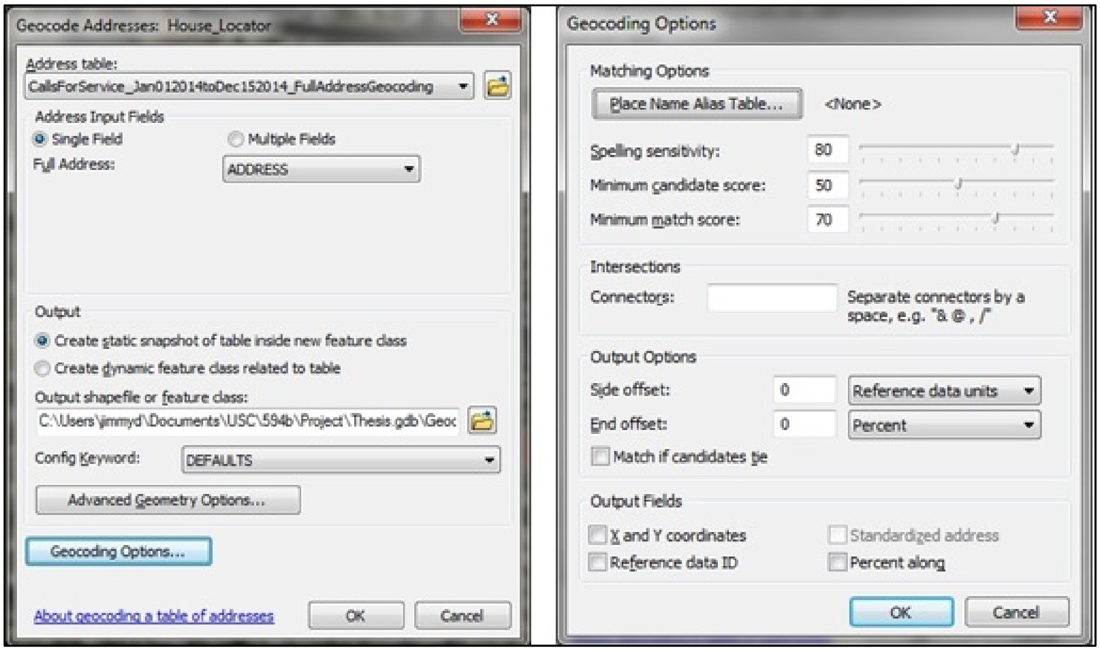


Figure 15. Single House Address Locator Setup for Geocoding Address Points

Using the above parameters, the Single House locator, with address points as the reference layer, successfully geocoded 8,155 locations from the revised table of 9,671 records; producing a matched rate of 84 percent, as shown in Figure 16.

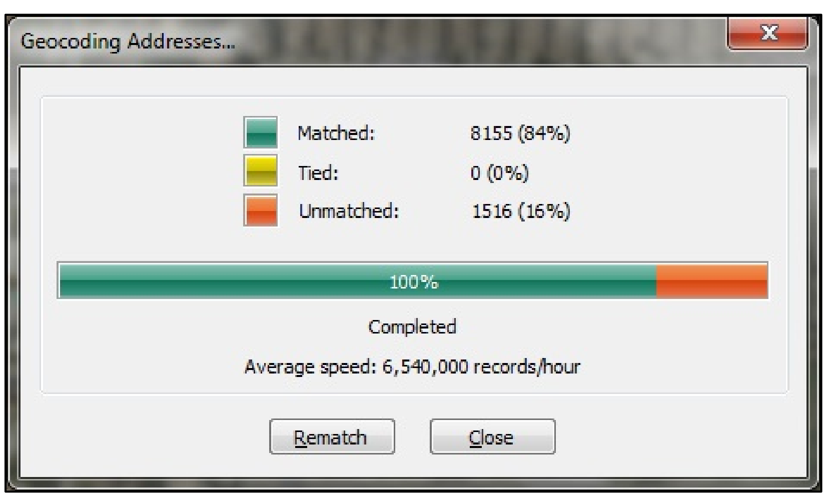


Figure 16. Geocoding Results from Single House Locator

Whereas Figure 17 shows that 8,148 addresses geocoded within the city limits, with seven locations verified outside Brea's city boundary. Results from Figure 17 show that unmatched addresses derived from the Single House locator could be mitigated in the future by adding the unmatched addresses to the address point reference data to improve the match rate.

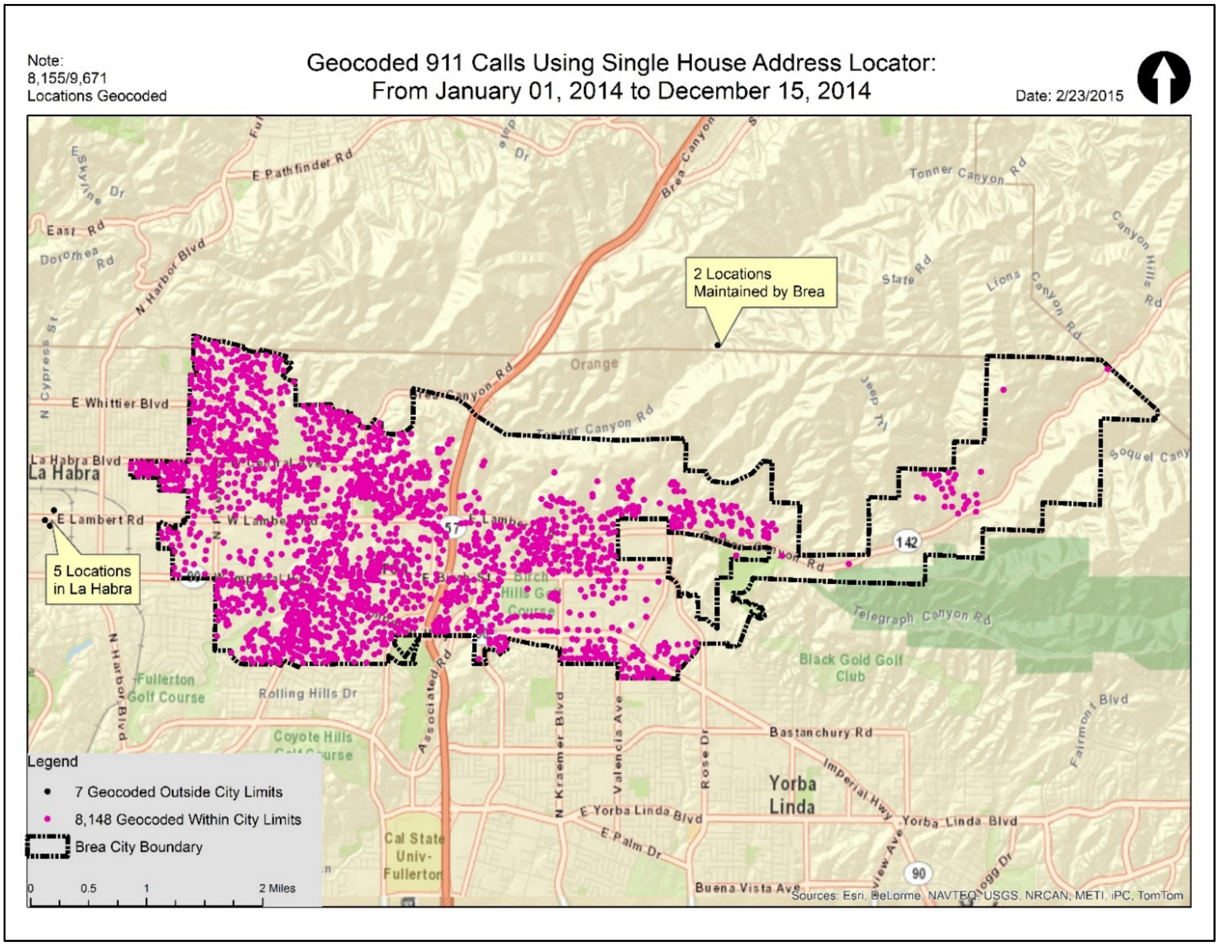


Figure 17. Geocoded Results (8,148 out of 9,671) from Single House Address Locator

4.4 Dual Ranges Locator

The Esri's US Address—Dual Ranges (will be referred to as Dual Ranges) locator style is commonly used to geocode addresses. Benefits of a dual ranges address locator include more flexibility in verifying addresses, compared to a single house locator. For instance, in a dual ranges locator, addresses are geocoded and verified as long as they fall within the assigned range of values from the left and right (odds/evens) sides of a given street segment (Esri 2014), shown in the example in Figure 18.

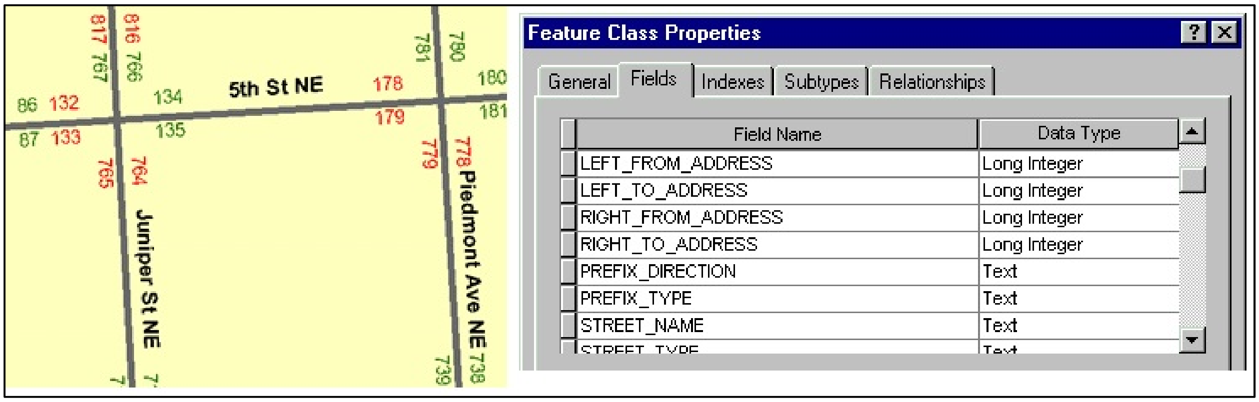
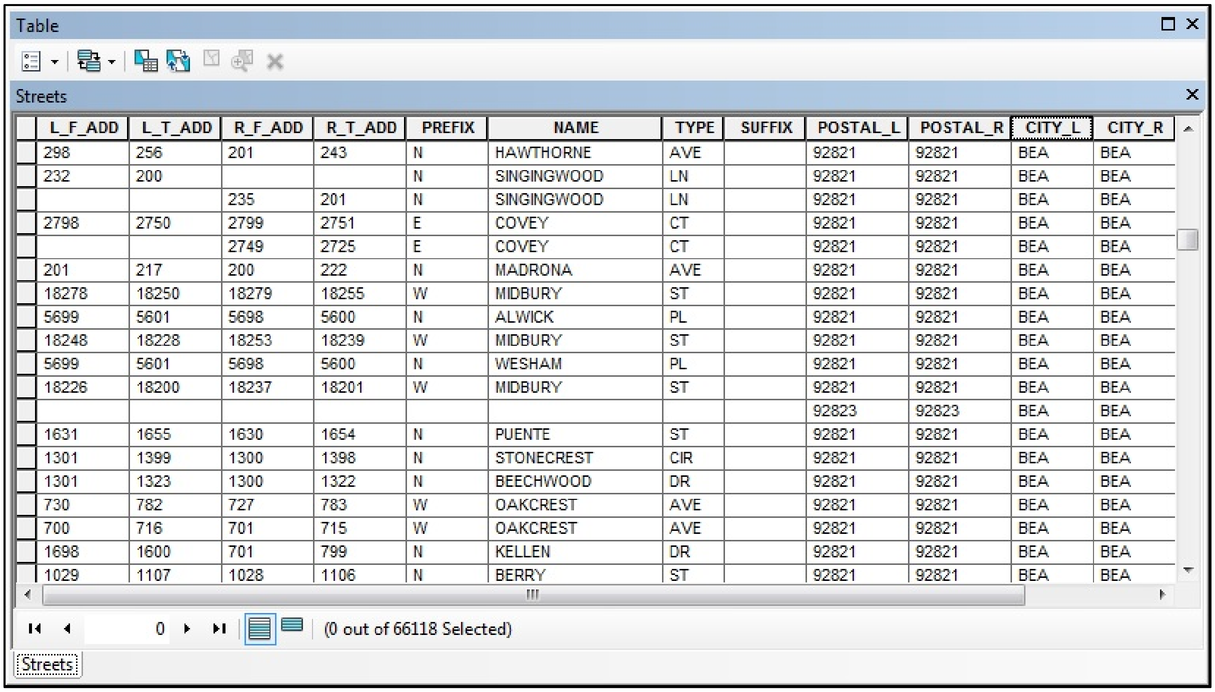


Figure 18. Example of the reference data used for a dual ranges address locator (Esri 2014)

Also, the dual ranges address locator can designate the side of the street segment where the address is located, resulting in less ambiguity for first responders. For Brea, the dual ranges address locator uses a polyline based street segment feature class, with values for left and right sides for each segment, or feature. For instance, each feature in the reference data for the dual ranges locator denotes a street segment with two ranges of addresses that fall along that street segment, one for each side of the street (Esri 2014).

In this analysis a street/centerline feature class is assigned as a reference layer for the Dual Ranges address locator style. Each street segment has a beginning and an end address number range for each side of the street, as well as street name information. In addition, the reference layer also includes fields that contain the street's prefix direction, prefix type, street type, suffix direction, ZIP Code, and municipal code information for each side of the street, as shown in Figure 19. Further, each street segment also supports normal block ranges, alphanumeric addresses, and contains cross-street information for searching by intersections (Esri 2014).



Table

Streets

L_F_ADD	L_T_ADD	R_F_ADD	R_T_ADD	PREFIX	NAME	TYPE	SUFFIX	POSTAL_L	POSTAL_R	CITY_L	CITY_R
298	256	201	243	N	HAWTHORNE	AVE		92821	92821	BEA	BEA
232	200			N	SINGINGWOOD	LN		92821	92821	BEA	BEA
		235	201	N	SINGINGWOOD	LN		92821	92821	BEA	BEA
2798	2750	2799	2751	E	COVEY	CT		92821	92821	BEA	BEA
		2749	2725	E	COVEY	CT		92821	92821	BEA	BEA
201	217	200	222	N	MADRONA	AVE		92821	92821	BEA	BEA
18278	18250	18279	18255	W	MIDBURY	ST		92821	92821	BEA	BEA
5699	5601	5698	5600	N	ALWICK	PL		92821	92821	BEA	BEA
18248	18228	18253	18239	W	MIDBURY	ST		92821	92821	BEA	BEA
5699	5601	5698	5600	N	WESHAM	PL		92821	92821	BEA	BEA
18226	18200	18237	18201	W	MIDBURY	ST		92821	92821	BEA	BEA
								92823	92823	BEA	BEA
1631	1655	1630	1654	N	PUENTE	ST		92821	92821	BEA	BEA
1301	1399	1300	1398	N	STONECREST	CIR		92821	92821	BEA	BEA
1301	1323	1300	1322	N	BEECHWOOD	DR		92821	92821	BEA	BEA
730	782	727	783	W	OAKCREST	AVE		92821	92821	BEA	BEA
700	716	701	715	W	OAKCREST	AVE		92821	92821	BEA	BEA
1698	1600	701	799	N	KELLEN	DR		92821	92821	BEA	BEA
1029	1107	1028	1106	N	BERRY	ST		92821	92821	BEA	BEA

0 (0 out of 66118 Selected)

Streets

Figure 19. Street Reference Layer for Dual Ranges Locator Table in ArcMap

The Dual Ranges locator also was assigned similar parameters to the Single House locator for comparison purposes. Spelling sensitivity, minimum candidate score, and minimum match score are designated with values similar to the Single House Locator, shown in Figure 20. Using the Dual Ranges address locator and the street reference layer, resulted in a matched rate of 96 percent. A total of 9,250 out of 9,671 addresses geocoded successfully, as shown in Figure 21. In addition, all of the geocoded locations are spatially verified by using ArcMap to analyze that all the geocoded points are within the Brea City limits, depicted in Figure 22.

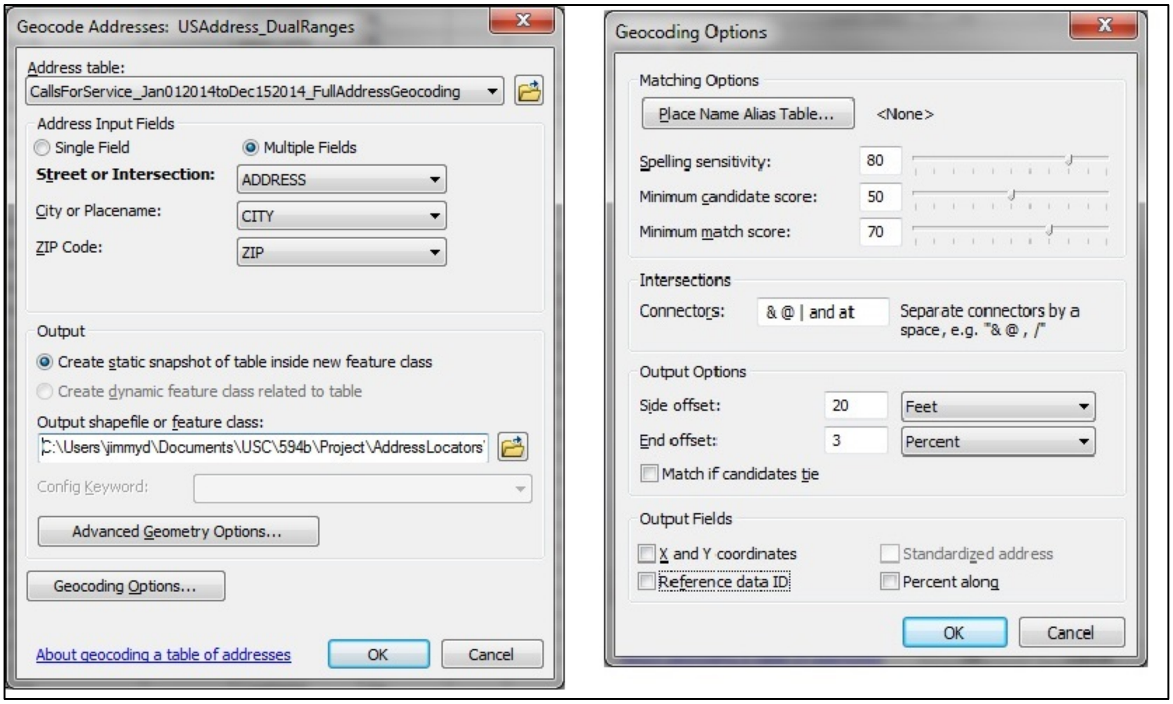


Figure 20. Dual Ranges Address Locator and Street/Centerline Feature Class

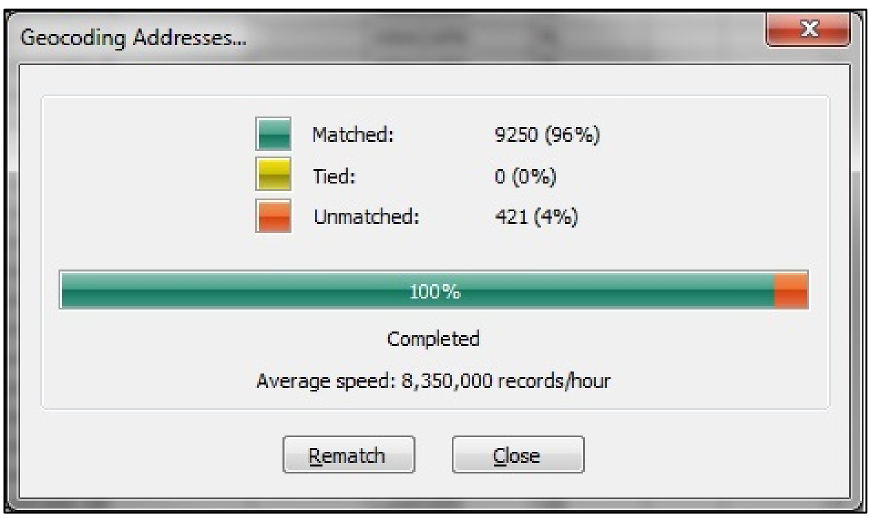


Figure 21. Geocoded Results from Dual Ranges Address Locator

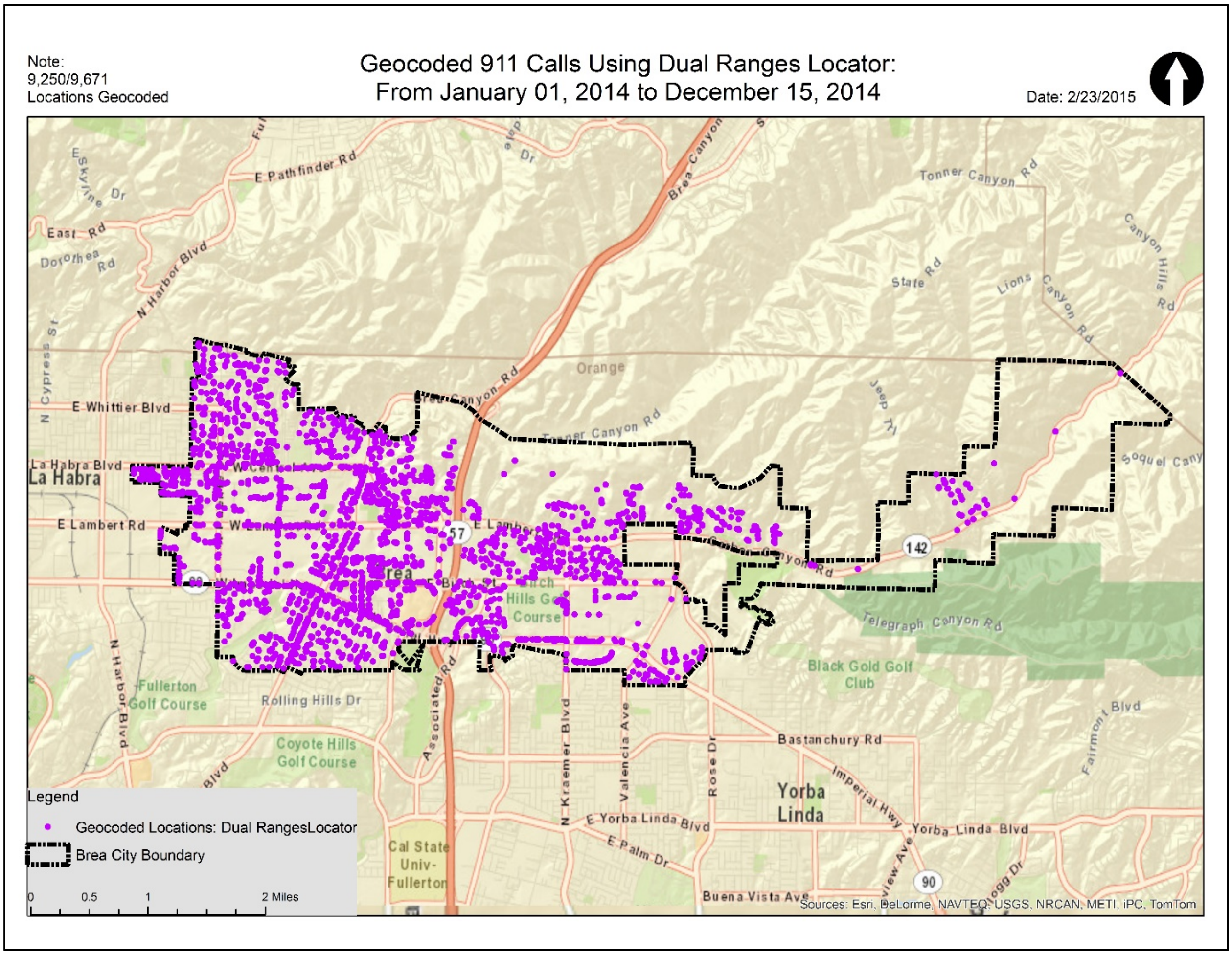


Figure 22. Geocoded Results (9,250 out of 9,671) from Dual Ranges Address Locator

4.5 Accuracy Comparisons

The geocoded results produced by the Single House and Dual Ranges locators show that there are many options to verify calls-for-service locations. From the geocoded results, it seems that the Dual Ranges address locator style, with the street/centerline reference data, performed much better than the address point based Single House locator. In most instances, the criterion assigned to the Dual Ranges locator results in a higher match rate than the Single House locator. For example, in the reference dataset for the Dual Ranges locator, the street segment for Laurel Avenue has a range from 200 to 299; therefore, any addresses geocoded in that given range will result in a match. On the other side, the Single House locator only produces a geocoded address if there is an exact match to the reference data (i.e. 216 Laurel Avenue). In most cases, the flexibility of the Dual Ranges locator produces a higher geocoding matched rate than the Single House locator. However, in some instances, the geocoded addresses from the Dual Ranges locator are 40 to 80 (or more) feet off from the actual locations, as shown in Figure 23. Therefore, in the case of Brea, geocoding by address points is the preferred method because Dispatch demands that each location be verified to exactly match the call location, resulting in faster response time to the 911 call.

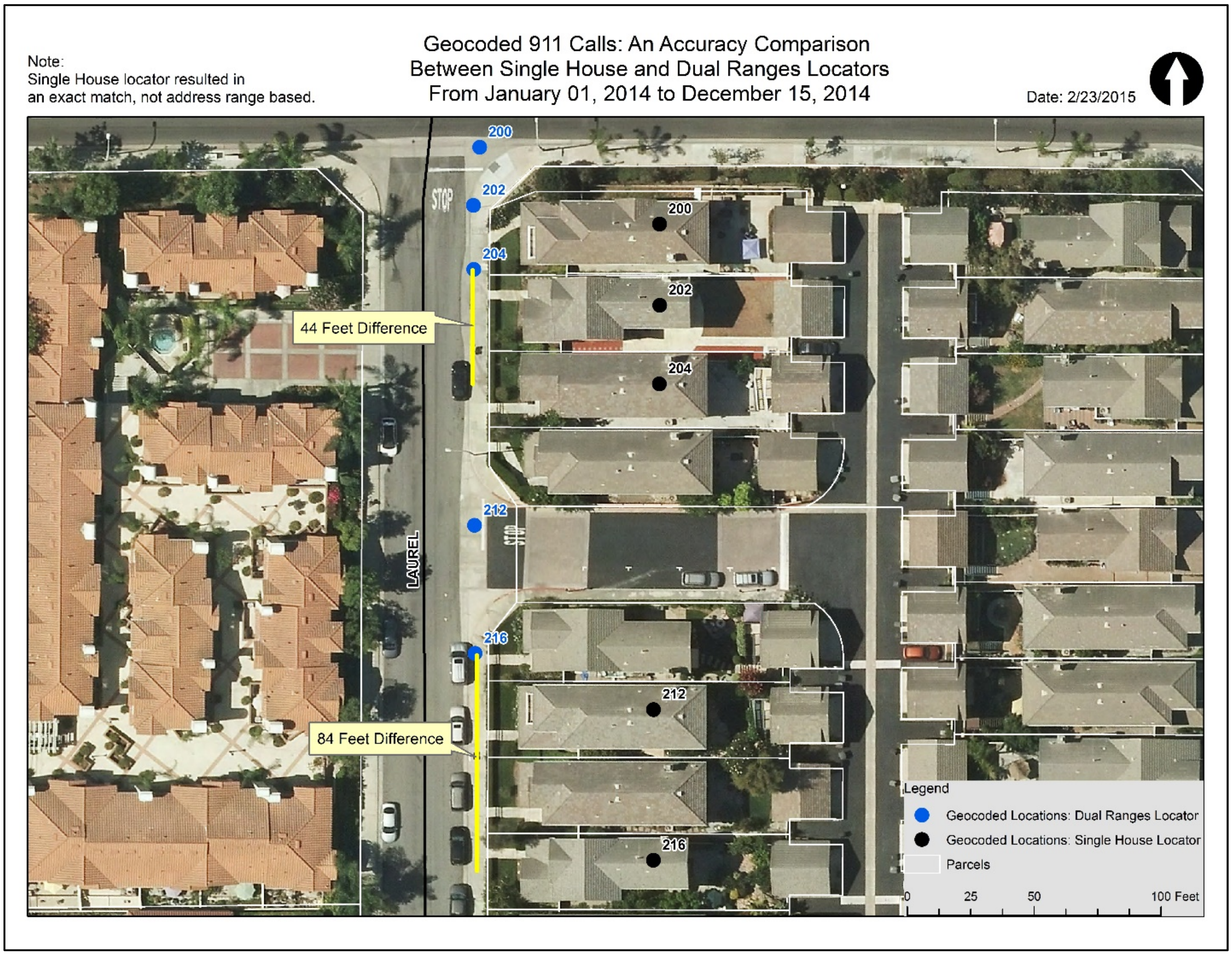


Figure 23. Comparisons of Geocoded Results

As an example of performance, from Figure 23, 204 Laurel Ave and 216 Laurel Ave are 44 to 84 feet off, when compared to the geocoded results from the Single House locator. The difference in Figure 23 might not seem catastrophic, but when medical aid is urgently needed, every second counts. Moreover, as shown in Figure 24, the Dual Ranges address locator geocoded 131 Kraemer Blvd to a location that is over 700 feet away from the actual property. Overall, the geocoded results shown in Figure 24 are off between 300 to 700 feet from the physical locations.   In contrast, the address points based Single House address locator geocoded the location to the exact building.

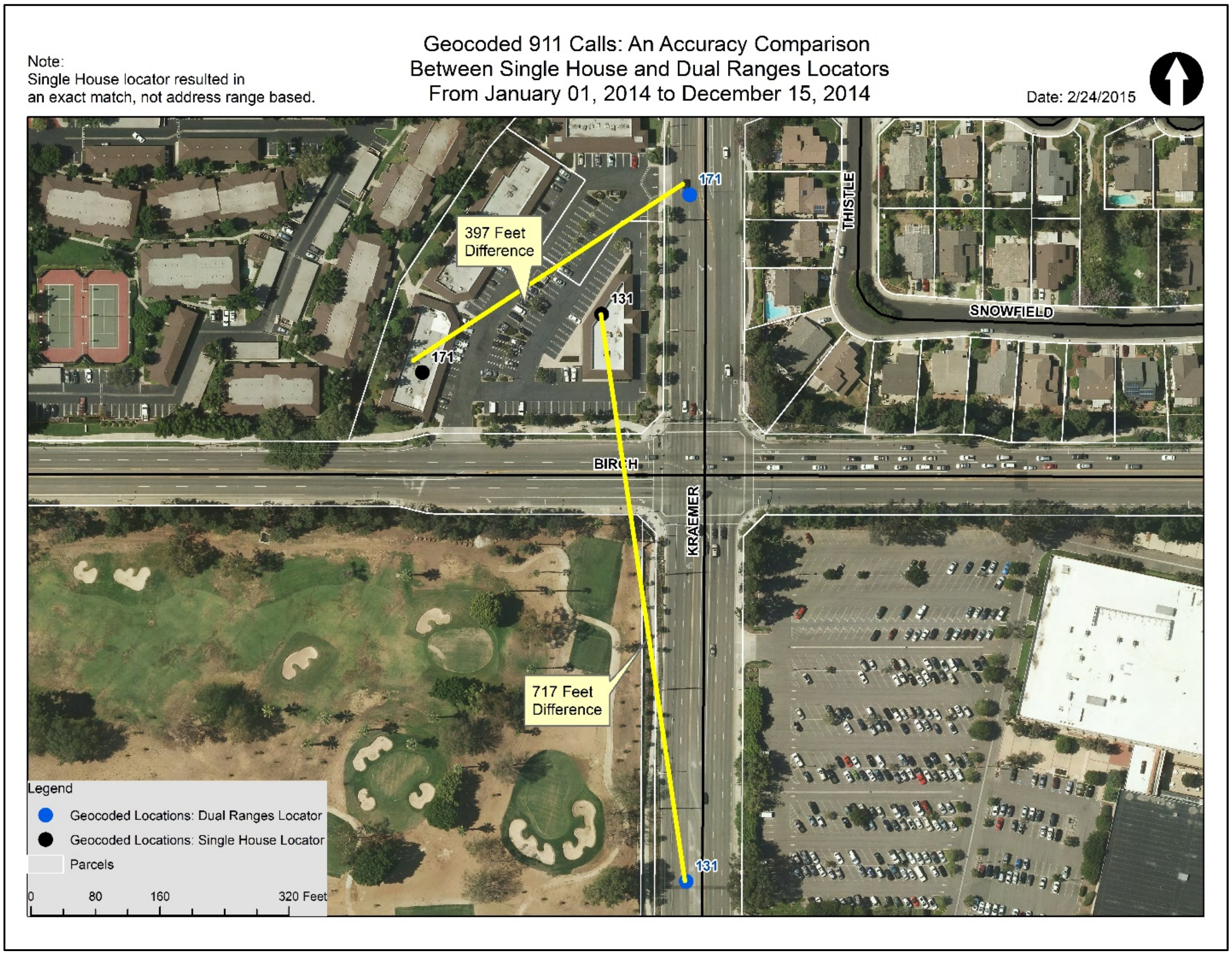


Figure 24. Analysis of Geocoded Results

Ideally, Brea Dispatch requires that all calls-for-service geocode to the exact location. The more time first responders take to arrive at the scene of the incident, the less they have to attend and help. In Brea, precision is at the utmost importance when it comes to responding to calls-for-service. Therefore, in Brea, geocoding by address points is the preferred method because Dispatch requires that all calls-for-service location verified exactly to the call locations, resulting in faster response time and enhanced services provided to the community.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

The purpose of this thesis is to present an objective analysis for comparing how different reference datasets and address locators perform, to determine the geocoder that works best within a given organization. The geocoding system in Brea City CAD is closely integrated into other core operational and workflow systems, and tailored to the type of data it encounters. This has produced results of sufficient quality for a range of users, including public safety, Police Dispatchers, and first responders (Goldberg et al 2013). For instance, the ongoing maintenance of a map-based CAD system is critically important for public safety, since it can provide accurate and on-demand information to first responders. The process of updating an existing CAD system with GIS layers, such as address points and street ranges are laborious, expensive, and time intensive (as demonstrated in the workflow model). Nevertheless this effort is deemed extremely worthwhile since the outcome potentially saves lives.

In addition, this research aims to promote the interagency cooperation and data sharing within the GIS community who supports CAD systems for local government agencies throughout the United States. There are many benefits for an interagency CAD system, such as shared deployment costs, better management of GIS datasets, consistency, and more knowledge sharing opportunity among the GIS community. Unfortunately, at this time, similar to other agencies in Southern California, Brea’s proprietary CAD system is an obstacle for sharing resources with neighboring agencies.

Addresses help individuals to locate one another in this challenging world (Zanbergen 2008). Geocoding is a topic that has been greatly studied and examined in many fields, including local government and public safety agencies. The process of geocoding provided an extended understanding on its many uses, for example the investigation of Dengue fever in Africa

(Goldberg 2011). For CAD, one of the most critical components for Dispatchers is to accurately and quickly verify the location of a distress call to provide timely response. For Dispatch, this involves geocoding each call to the exact location of the caller. Therefore, Dispatch prefers an exact match to reduce confusion for first responders and to minimize potential errors, such as driving to a wrong location.

The transition to a GIS centric CAD system proved to be full of challenges, with extensive data conversion issues, learning new software, and unfamiliar graphical user interfaces. Intergraph's computer aided dispatch system uses customized graphical user interfaces and tools, which have a different look and feel compared to Brea's previous map-less CAD system. However, in the end, these challenges provided a great learning opportunity for the Dispatchers to become more comfortable using the system.

In the City of Brea, Dispatch received over 16 thousands calls-for-service in 2014 (Brea Police Department). This thesis examined and tested the accuracies of address locators used to geocode, or verify 911 calls. Verifying calls-for-service to its exact location is critically important, resulting in faster response time. Therefore, Dispatch demands that its CAD system geocode each call to the physical location. This is only possible using an address point data reference with the geocoder. On the other hand, while the street range data reference helped to locate many 911 calls, in some cases it resulted in greater ambiguities than address points. When a location fails to verify the exact physical location, it required more time and effort by first responders to offer assistance.

A total of 9,671 addresses were used to compare the different levels of accuracy and matched rates from multiple address locators. The geocoding results show that when addresses are geocoded using the street range address locator, the matched rate is 96 percent, compared to

84 percent matched rate in the address point locator. However, a closer examination of the geocoded features from the street range locator showed some discrepancies. Some of the features are off by 30 to 700 feet from the actual calls-for-service locations. On the other hand, when using the address point locator, each geocoded feature matches correctly to the physical location, without any ambiguities. Validating 911 calls correctly to serve the community is an important and integral part within public safety. The ability to dispatch calls efficiently and timely could result in a greater chance to saves lives in life-threatening situations, where faster response time is most critical. Therefore, Brea's Dispatch preferred methodology for addressing verification is through address points.

The methodologies and discussions described in this thesis show that an accurate, well-tested address point locator is a favored solution to street range address locator for geocoding 911 calls. An address point based locator, maintained by city staff on a consistent basis, should also improve the overall match rate. A street range address locator is useful in a situation where the address point locator failed to geocode a location. Furthermore, matched rates from the geocoding results do not always verify to the physical call location. When it comes to geocoding addresses, or the need to confirm a location for billing purposes, maintaining an accurate, consistent address point layer is not only useful for Dispatch, but citywide. In addition, this work could represent a model for future interagency cooperation among neighboring cities and counties who may want to deploy a sustainable GIS-based CAD system, with shared costs and resources.

5.1 Next Steps

Updating spatial data for a mission-critical system like CAD is a daunting task within the GIS community. Results of the research show the superiority of address points when compared to street address ranges in a CAD environment for Brea's Dispatch, in particular when it comes to geocoding accurate, precise calls-for-service locations. However, future work in this subject could include adding a third address locator. For example, a composite address locator, which includes multiple address locators for geocoding locations may be the preferred tool, since it could include both address points and street ranges, resulting in more matched locations.

The next step in this research is to examine how response time is calculated because some 911 calls are more urgent than others (Table 3). Furthermore, Dispatch determines the severity of each call, based on the information received from the caller. For example, a Code 3 caller with a life-threatening emergency will receive faster response time than a Priority 3 caller who is requesting assistance due to a minor fender-bender.

Table 3. Monthly Response Times from January to November, 2014 (Provided by Brea Police 2014)

MONTHLY AVERAGE	CODE 3 (MINUTES)	PRIORITY 1 (MINUTES)	PRIORITY 2 (MINUTES)	PRIORITY 3 (MINUTES)
JANUARY	2.59	6.12	7.21	11.31
FEBRUARY	3.31	5.27	7.28	11.23
MARCH	3.37	6.00	8.45	12.50
APRIL	3.25	3.44	7.48	11.00
MAY	3.48	5.48	7.42	11.14
JUNE	3.31	5.26	7.03	11.25
JULY	3.35	5.28	7.33	12.58
AUGUST	4.11	6.06	7.04	12.02
SEPTEMBER	3.39	5.46	7.30	12.10
OCTOBER	3.29	6.54	7.28	11.55
NOVEMBER	3.30	3.43	7.39	10.56

In addition, measuring response time is also a challenging task (sometimes impossible). Each response varies based on multiple environmental and human influences: weather, time of day, traffic conditions and geocoding results.

Moving forward, the data, examples, and methodologies used may provide some potential usefulness for other government agencies who are considering migrating to a GIS based CAD system. Though it may seem simple to assign address points as the main reference data source for geocoding addresses, agencies with minimal funding sources and GIS staff may not have the capabilities to maintain such a labor intensive dataset. Rather, it might make more economic sense to use a street range data layer to geocode calls-for-service. Overall, each agency needs to determine its preferred levels of accuracy, when validating calls-for-service locations.

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APPENDIX A: Brea GIS Layers for CAD

LAYER NAME	FORMAT	ATTRIBUTES	SOURCES
Address Points	Point Feature Class	ADDRESS, HOUSENUM, ADDR_PD, ADDR_SN, ADDR_ST, UNIT, SUFFIX, CITY, STATE, POSTAL, NAME, BREA_ID, LAT, LON, ALIAS1, ALIAS2, ALIAS3, ALIAS4, ALIAS5, GROUP, TELEPHONE	City of Brea
Streets	Line Feature Class	L_F_ADD, L_T_ADD, R_F_ADD, R_T_ADD, PREFIX, NAME, TYPE, SUFFIX, FCC , POSTAL_L, POSTAL_R, SEG_LEN, SPEED, ONE_WAY, F_ZLEV, T_ZLEV, CITY_L, CITY_R, BREA_ID, FULL_NAME, ALIAS1_NAM, ALIAS2_NAM, ALIAS3_NAM, ALIAS1_PRE, ALIAS2_PRE, ALIAS3_PRE, ALIAS1_TYP, ALIAS2_TYP, ALIAS3_TYP, ALIAS1_SUF, ALIAS2_SUF, ALIAS1_SUF3	City of Brea
Parcels	Polygon Feature Class	APN, SITEADDR, HOUSENUMBR, OWNER_NAME	City of Brea
Police ESZs	Polygon Feature Class	ESZ, VALUE	City of Brea
Police Beats	Polygon Feature Class	BEAT, NAME	City of Brea
Fire ESZs	Polygon Feature Class	ESZ, VALUE	City of Brea
City Boundary	Polygon Feature Class	AREA, PERIMETER, CITY_NAME	City of Brea
Surrounding Cities	Polygon Feature Class	AREA, PERIMETER, CITY_NAME	City of Brea
Police Stations	Point Feature Class	Name, ADDRESS, Zipcode, City, Agency	City of Brea
Fire Stations	Point Feature Class	Name, ADDRESS, Zipcode, City, Agency	City of Brea
POI	Point Feature Class	NAME, ADDRESS	City of Brea

LAYER NAME	FORMAT	ATTRIBUTES	SOURCES
Parks	Polygon Feature Class	NAME, ADDRESS	City of Brea
Schools	Polygon Feature Class	NAME, ADDRESS	City of Brea
3" Imagery	Raster Dataset	Cell Size (X,Y), 3" Resolution	City of Brea

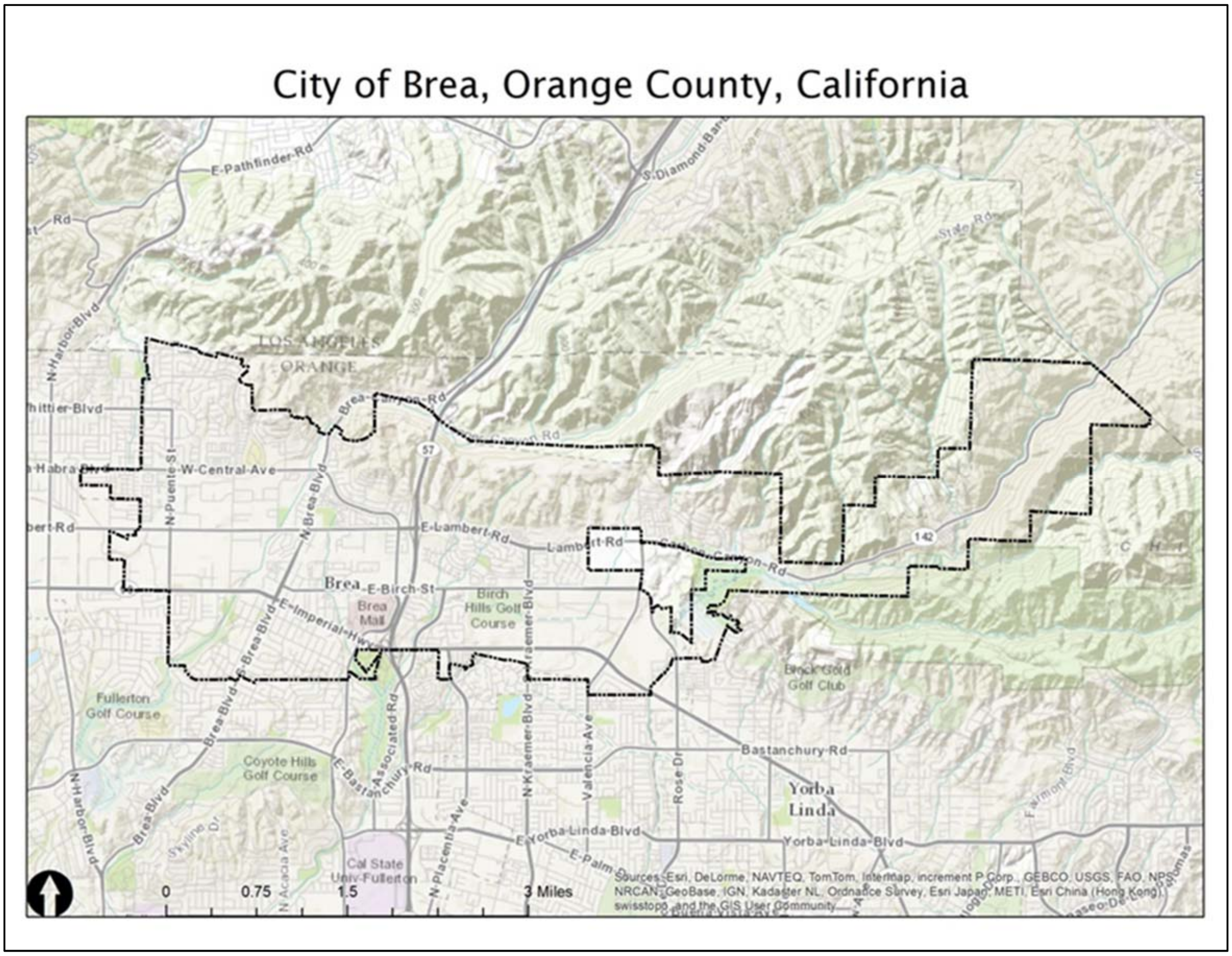
APPENDIX B: Software for Building Brea CAD System

SOFTWARE	SKILLS	EXPERIENCE
Esri ArcGIS (ArcMap)	Data editing and georeferencing	16 years
Esri ArcGIS (ArcCatalog)	Geodatabase design, feature class management, Geocoding and creating Address Locator	16 years
Intergraph GeoMedia Pro w/iMapEditor	CAD data conversion	7 years
Intergraph iDispatcher	Test converted CAD data after map roll	7 years

APPENDIX C: Brea Street Type Field Definition

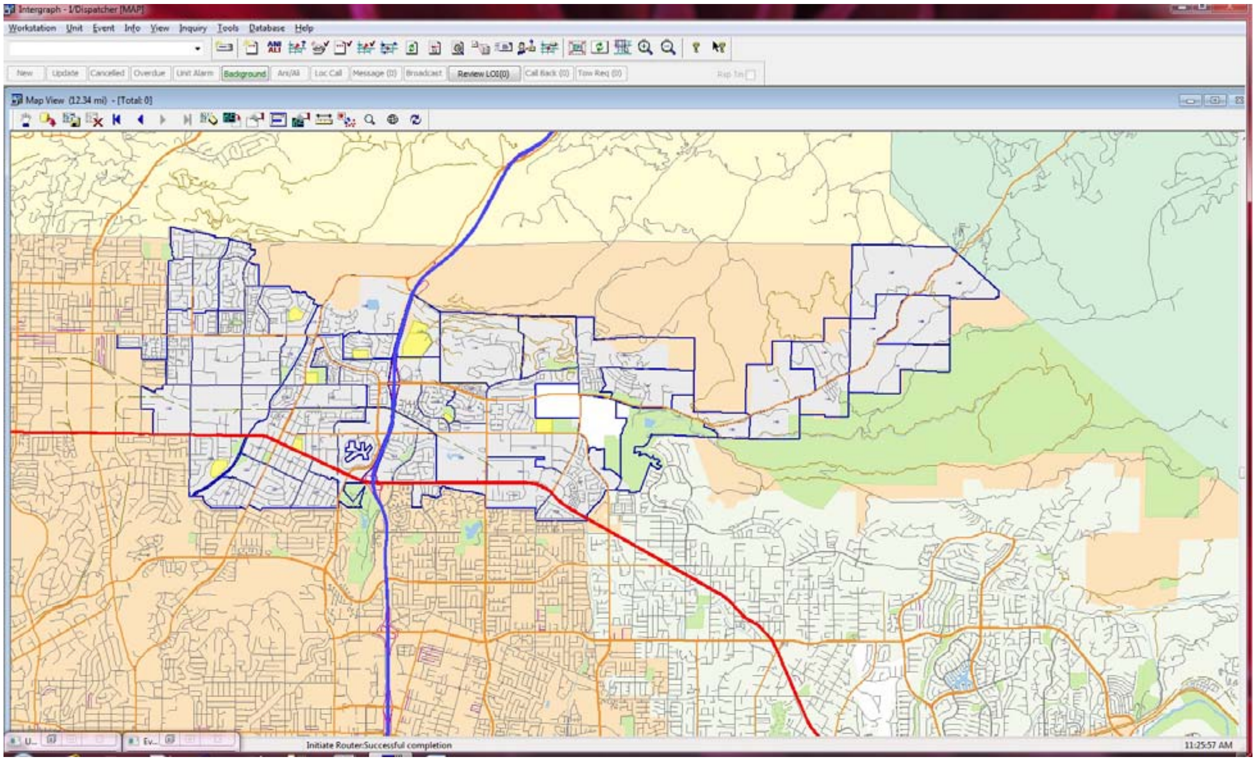
STREET TYPE NAME	GIS
AVENUE	AVE
BOULEVARD	BLVD
CIRCLE	CIR
COURT	CT
DRIVE	DR
LANE	LN
LOOP	LP
PARKWAY	PKWY
PLACE	PL
ROAD	RD
STREET TYPE NAME	GIS
STREET	ST
TERRACE	TER
TRAIL	TRL
WAY	WY

APPENDIX D: Study Area: City of Brea Boundary



Projection: Projected Local State Plane: CA Zone 6 (US Feet)

APPENDIX E: City of Brea’s Computer Aided Dispatch



Source: City of Brea. 2014. Intergraph’s CAD Mapping System.