LOCAL DEVELOPMENT, LOCAL DATA: A GEOSPATIAL STUDY OF SMALL-AREA CHANGE USING BUILDING PERMITS IN AUSTIN, TEXAS

A thesis

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Abstract

This investigation utilizes municipal records to explore how local datasets and spatial analysis tools, specifically building permits and GIS, may be used to study land development. The goal of this exploration is to provide planners and policy-makers with information to help them assess the local physical environment. In order to evaluate the effectiveness of this analytical method, a comparative analysis is performed between the permit dataset and data from the U.S. Census Bureau. Additionally, programs and changes related to development are examined to demonstrate potential uses of this municipal data.

The City of Austin, Texas, is the context for this study, and the permit records used span two decades from 1990 through 2009. The case studies analyzed include Austin's Smart Growth Initiative and the Balcones Canyonlands Preserves conservation project, as examples of proactive and explicit land use decisions. Additionally, shifting neighborhood demographics and gentrification provide a scenario for studying the changes that have resulted from residential mobility decisions.

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Chapter 1 Introduction

The aim of my thesis is to explore the spatial visualization and analysis of building permit data, with the goal of helping planners and policy-makers see what is happening in the physical environment around them. Specifically, I used building permit records from the City of Austin, Texas, and GIS technology to illustrate residential land development over a period of twenty years from 1990 through 2009. As part of my study, I reviewed this data source for content, format and completeness.

In addition to the building permit records, I included housing data from the U.S. Census Bureau in my maps so that comparisons might be drawn between the two datasets. Further, I added relevant data to illustrate how development occurred in relation to a conservation project, a policy initiative aimed at reducing sprawl, and known areas of gentrification and demographic shifts. The aim of my research is not to determine solutions to any development related issues, but rather to illustrate some of the evidence that can be gathered from a spatial analysis of permit data in order to inform interested parties and improve debate and decision-making.

I believe that it is important to pay attention to land development and its effects in order to create and maintain healthy communities. Construction of new homes and businesses impacts the makeup of our neighborhoods, towns and cities. Beyond helping to shape the physical environment, development also affects the social dynamics of neighborhoods, as well as economic and environmental issues.

Data is an important foundation in all planning and policy-making, decisions regarding land development being no exception. Information can be very powerful, and therefore it is important that it be from a consistent and reliable source so as to reduce potential negative impacts of inaccurate or incomplete information. The U.S. Census Bureau is a primary data source for many areas of research, including housing and development. The decennial census provides accurate counts of the population and housing units every ten years. The Bureau recently initiated the American Community Survey (ACS) in 2005 in an effort to improve the timeliness by providing sample data on a continuous basis. The ACS data suffers from significant sampling error at the census block group and tract summary levels. This is exactly the scale necessary to track and analyze development patterns within a city or metropolitan area.

Administrative records, such as the building permit database used in this research, are another available data source for planning and policy-making and may be able to fill some of the gap for analyzing development patterns. Principal among the concerns with using these records is standardization in format and information collected across agencies and municipalities. However, the tradeoff between timeliness and accuracy present between census datasets is not an issue for administrative datasets as they are continuous records kept on a local level. Therefore, it is useful to consider these resources as a possible supplement to census information.

Much of the value of data depends upon how it is organized and communicated. Increasingly researchers are utilizing and advocating the use of GIS technology as a way to disseminate information. Heather MacDonald and Alan Peters argue that “Presenting analyses in maps rather than tables offers a far more powerful and graphic communication strategy, one that can engage decision makers and the public in new sorts of debates about spatial inequality or patterns of growth and decline that would be difficult to grasp if results were presented only in tables” (MacDonald and Peters 2011: 2).

In summary, knowledge of land development patterns within a city or metropolitan area is important to building and maintaining communities, but the decennial census and American Community Survey both have serious deficiencies in this regard. Combining building permit records and GIS technology could prove useful in studying land development patterns by providing continuous and detailed information, while also allowing for individuals to examine the relationship of development to economic, environmental and various other factors.

The purpose of this thesis is to evaluate the use of building permits to study land development, focusing on the City of Austin, Texas. Chapter 2 reviews existing literature relevant to the study presented in this paper. It contains a discussion of urban planning data needs and how small-area data, such as building permits, as well as census data and GIS, contribute to research in the field. The “Methodology” chapter provides a guide to the analysis performed in this thesis, defining the study area criteria and the datasets used. Additionally, it describes the

GIS techniques used in the comparative analysis between building permit and census data, as well as the steps taken to visualize and assess the land development issues related to the conservation, sprawl and gentrification case studies. Chapter 4 discusses the primary limitations and challenges of working with building permit and census data found in this study. The fifth chapter takes a close look at the structure of Austin's building permit records and describes the data cleaning procedures necessary to prepare a final file for spatial-temporal analysis. "Chapter 6 – Results and Analysis" follows the "Methodology" chapter, demonstrating several different visual and analytical techniques through data comparison with the census and assessment of the case studies. The final chapter summarizes the results of the thesis; drawing conclusions regarding building permit data use in assessing land development and making recommendations for a more standardized data structure.

Chapter 2 Literature Review

2.1 Background

2.1.1 Data Needs for Urban Planning

Planners aim to affect the physical form of a place, and in working towards this goal planning professionals must have relevant data on land use and development including use types, placement, size and construction costs. In order to plan effectively, they must also understand the economics, demographics and politics of the places they aim to shape physically (MacDonald 2008).

In her work on city planning and the census, Heather MacDonald emphasizes that physical, economic and demographic data are not only essential to good planning, but that the decennial census, which disseminates this sort of information has evolved in concert with planning in the United States (MacDonald 2008). MacDonald identifies census data as part of "a national information infrastructure" and argues that, "Without reliable, consistent, and spatially comparable census data, our ability to invent creative solutions to complex urban challenges would be far more limited" (MacDonald & Peters 2011: 1). As it is the primary and central source of data related to planning needs, planners and policy-makers have long advocated for the U.S. Census Bureau to collect data on a more local and detailed level. For the first half of the 20th century, comprehensive city plans suffered from missing information, as data was not available on the necessary level. To address this issue, initiatives were undertaken such as The 1929 Regional Plan of New York; a major private sector effort aimed at demonstrating the value of accurate data. Additionally, lacking information at an appropriately disaggregated level, local surveys were frequently conducted to supplement the census. Over 300 local surveys were performed between 1909 and 1915 alone. However, high costs and a lack of standardization made these surveys inefficient and reduced their accuracy and therefore their applicability (MacDonald 2008).

The need for small-area datasets was addressed, to a degree with an expansion of the geographic areas covered between the 1950 and 1960 censuses. More coverage by the Census Bureau meant an improved data cache of smaller areas. During this period, the number of census tracts surveyed increased from 12,000 to 23,000 (MacDonald 2008). Today there are approximately 65,000 census tracts in addition to smaller block group and block geography units assessed by the U.S. Census (Proximity 2011). Development of the census long form and more recently, the American Community Survey, are further responses to the data needs of planners. However, data at the block or parcel level remains necessary to achieve a detailed picture of a neighborhood context for planning. Researchers acknowledge that the wide range of data gathered by local governments, much of it address-based, has great potential to supplement ACS estimates. MacDonald and Peters conclude that: “we could answer many questions about estimating need, assessing outcomes, and modeling change if we were to integrate local administrative data with annual ACS releases” (MacDonald & Peters 2011: 161).

2.1.2 Need for Small-Area Datasets

A review of the literature regarding “small-area data” reveals that “small” is relative. Depending on the purpose, a “small area” can “vary in size from less than an acre to thousands of square miles, and from a mere handful of residents (or none at all) to many millions" (Smith and Morrison 2005: 2). In certain analyses, state-level information can be identified as small-area data. For local and regional analysis, census tracts, geographic units containing an average of 4,000 individuals, are often defined as small-area datasets, while data for actual city blocks or even individual parcels provide more detailed information for assessment. Censuses, administrative records, and sample surveys are the primary sources of small-area information (Smith and Morrison 2005). This study will define a small-area dataset as lower-level information gathered from local administrative records, and comparisons will be made to census tract level data. Specifically, the focus will be on citywide building permit data collected on a parcel level.

In recent decades, planners and policy-makers have recognized the usefulness of small-area datasets in assessing community needs and planning for their futures. "Small-area data can be used to allocate government funds, determine eligibility for entitlement programs, delineate political and electoral boundaries, monitor the effectiveness of public policies, select sites for public facilities, and develop program budgets" (Smith and Morrison 2005: 3). The Urban Institute published an entire catalog of small-area datasets that could be used to address topics including the economy, education, security, health, social services and the environment among others (Coulton 2008). A need for data with a great deal of detail and accuracy has led planners to look at data collected at a local level. Projects to develop "neighborhood indicators" based on local administrative records have been initiated across the nation and quickly picked up by community groups as advocacy tools (Coulton 2008). The National Neighborhood Indicators Project (NNIP) advocates for a participatory process to form indicators capable of affecting citizen action and public policy making (Sawicki and Flynn 1996). The Brookings Institute began the Urban Markets Initiative in 2003 supporting access to and higher utilization of small-area datasets (Coulton 2008).

Small-area datasets are becoming more popular and more necessary for analysis as power and government programs become increasing decentralized in the United States, shifting the responsibility of social and economic welfare from the federal to state and local levels (Sawicki and Flynn 1996, Marker 2001, Smith 2003). The vast majority of land use decisions are made at the local level. For instance, most municipalities have their own zoning bylaws. As another example, city and town governments most often handle new roads and other infrastructure needs. This increases the need for development data analysis at a community scale (Allen et al. 1996).

Datasets with detailed information related to construction, housing and infrastructure are especially important due to fluctuating and unanticipated changes in development trends. In 2005 testimony before Congress, Paul Farmer, AICP, Executive Director of the American Planning Association, emphasized the importance of low-level development data citing studies that projected a doubling of land development in the United States between 2000 and 2030. This surge in growth would be accompanied by an estimated $20 trillion investment in construction and redevelopment (Farmer 2005). These projections will go unrealized due to an economic recession that slowed development beginning in 2007. This change did not, however, invalidate Mr. Farmer's call for more focus on small-area development data. The unanticipated change actually highlights the importance of frequent and continuous development related datasets for analyzing and adapting to trends. It is important for planners and policy-makers to be able to understand and track development in their efforts to guide it.

2.2 Data Sources

2.2.1 Census Data

The U.S. Census Bureau has long been a primary resource for a vast spectrum of data needs, including those of planners and policy-makers. The Bureau collects and makes available an array of social, economic, geographic and political information across the nation. Though this data is immensely useful in planning and policy analysis, there are several factors including the scope, frequency, scale and accuracy of census data, which lead to the conclusion that small-area datasets independent of the census could prove valuable. Rapid community changes and data demands of advancing technology are challenging and require information beyond the scope of what the census can deliver (Farmer 2005).

Census data is made available at varying levels of geography. The most comprehensive set of "small-area" data is available at the level of the census tract. A tract averages between 4,000 and 8,000 residents. The data available at the tract level includes data both from the 100% census (basic demographic and housing data collected via a form that goes out to all housing units, the so-called "short form") and more detailed data collected via a sampling process. Between 1940 and 2000, the sampling was done once every 10 years via the so-called "long form" – a much more detailed set of questions sent to a sampling of housing units. Census block groups provide information for smaller geographic areas and smaller sets of the population. However, this data is sometimes restricted due to privacy concerns as well as accuracy issues and resources (Coulton 2008). The average population of a block group is approximately 1,500 individuals. At the block level, it is possible to get only the basic demographic and housing data collected from the 100% census. A census block contained 100 persons on average in the 2000 Census (NCSU Libraries n.d.).

The infrequency of the U.S. Census, as well as the timing of data release and availability result in accuracy issues for rapidly changing communities (Sawicki and Flynn 1996, Smith 2003). The comprehensive census is performed once every ten years as required by the U.S. Constitution, Article I, Section II (U.S. Census Bureau 2012). The U.S. Census Bureau has recognized the need for more frequent data collection and responded to this with the American Community Survey (ACS). The Census Bureau started the ACS on a trial basis in 1996 and officially implemented it to replace the long form of the decennial census in 2004. The ACS is ongoing, through monthly surveys, with one-year, three-year and five-year averages reported. However, there is still a lag of at least a year from data collection to data release (U.S. Census Bureau 2011a).

Introduction of the ACS brought new challenges to data analysts. "Using spatially detailed information as a basis for spatially targeted decision making is more complex with the advent of continuous survey methodologies that improve timeliness but reduce precision" (MacDonald & Peters 2011: xi). Though more frequent than the decennial census, the ACS is still limited in applicability and scope (Farmer 2005). As with the previous "long form" decennial sample, no ACS data will be released at the block level for reasons of privacy and statistical validity. Additionally, only the five-year averages will survey populations at geographic levels as small as census tracts and block groups. Dr. Robert Groves, the Director of the U.S. Census Bureau touted the first release of five-year estimates in December 2010, stating "people will no longer have to wait a decade for the next look at detailed characteristics data for their small areas" (U.S. Census Bureau 2012). Though released annually, a critical review of this detailed data will still require a time lag because it averages several years. For example this initial release provided averages for the 2005 to 2009 time period, meaning that the data straddled the economic recession and the ACS won't show the impact of the recession clearly for several more years.

In addition, ACS estimates are less accurate than the decennial data due to a much smaller sample size. Though the reported response rates to the ACS are high, 98 percent in 2009, data is solicited from less than one percent of society each year (U.S. Census Bureau 2011a). Further the published margins of error for ACS data are sometimes over 100 percent (U.S. Census Bureau 2011a).

The Census Bureau collects data similar to that found in local records. They have building permit counts, for example. These particular records are even kept on a continuous monthly basis and published on the Bureau's website within a few months of collection. However, this information is not provided at the block, block group or census tract level. The lowest level it is aggregated to is the city, therefore not allowing for a more detailed neighborhood or block analysis (U.S. Census Bureau 2011c).

2.2.2 Small-Area Local Data

Census data is collected on the federal level. States, counties, cities and other municipalities also keep records regarding their populations and defining characteristics. Local datasets related to land development include planimetric maps, cadastral maps showing ownership at the parcel level, building permit records, and assessor's data assembled for purposes of annual property tax determination. In addition, many local jurisdictions now carry out their traditional mapping functions using GIS, maintaining various "data layers" of features that were previously included on paper maps. These include land use, roads, water features, parks, and community facilities.

This data is collected on multiple geographic levels and can contain various data fields, so it is often not compatible across cities, even within the same metropolitan region. Some jurisdictions have extensive GIS datasets, while others have just a few or none at all. It also requires a major effort to keep local data up to date. Land use has to be systematically surveyed for each update and so may be out of date by several years. Even records that are continually maintained can be completely different from one jurisdiction to another. For instance, the City of Austin, Texas, lies within Travis County. Both entities maintain databases of building permit records, and though Travis County tracks a larger area, the Austin data is more detailed, recording attributes such as construction square footage and valuation data (Austin City Connection 2011, Travis County, Texas 2011).

This thesis argues that data that is continuously recorded like building permits represents an underutilized resource for exploring the response to planning and policy initiatives at a very local neighborhood level not just at the larger city or town aggregate level for which it is already widely used. Further, this thesis reviews the benefits of analyzing these records in a spatial method at levels from the city to the block. Continuous records provide a complete and more comprehensive dataset than periodic surveys. The current status of the data also allows for up-to-date analysis at any time. For example, the Austin building permit records that will be used in this study are publicly available for the period of 1990 through the third quarter of 2010 (Austin City Connection 2011).

2.3 Benefits of Small-Area Data

What specifically will small-area datasets allow planners and policy-makers to do? Smaller datasets will increase the accuracy of analysis by providing more frequent, detailed and real data relative to the estimates that are currently provided by the U.S. Census Bureau. With better planning tools, we can streamline the efficiency of services and reduce the “hidden tax” of higher infrastructure costs (Farmer 2005). In addition, increased community participation and effectiveness of local organizations are often results of using small-area datasets (Coulton 2008).

Having the flexibility within a dataset to define the boundaries of an analysis area in several different ways is one important benefit of small-area datasets. Set geographic areas such as those used in the census lead to concerns about the modifiable areal unit. The Modifiable Areal Unit Problem (MAUP) results from discrepancies between spatially identified data and the geographic boundaries used to analyze this data (Mennis 2003). With boundaries defined in an arbitrary and static manner, analysis can be misleading or the results inconclusive. For instance, a census tract with a small population and large area could indicate low-density residential neighborhoods, or alternatively, there could be a small cluster of very high-density residential development in one area of the tract with the rest of the area being open space or commercial development. Analysis results can be dependent on the unit of analysis and results can vary depending on the zone or aggregation technique used for assessment. Obtaining data at the smallest possible geographic unit, such the parcel or address level can mitigate this concern by eliminating boundary issues and allowing for flexible analysis at multiple levels of geography (Coulton 2008).

In order to create programs or regulations designed to manage growth – or decline, as is happening in some places (Beauregard 2009) – planners first need to understand it. Overall according to McDonald and McMillan, "little is known about the spatial patterns of development because data is usually highly aggregated spatially" (as cited in Smersh et al. 2003: 62). Before addressing the issues of sprawl and development patterns we need to understand what these patterns look like and what is causing them. In order to do this we need data at a low level of geography and high level of detail. Once we have this information, it will be useful not only in assessing the current state of land use development and trends, but also in projecting what may happen in the future and where development may go, as well facilitating assessment of land development policies. Small-area datasets and GIS may be effective tools at multiple stages of the process in analyzing land use development patterns.

2.4 Challenges of Small-Area Data

Small-area datasets have numerous benefits, but also many challenges associated with them. The data is more difficult to obtain and standardize than higher-level information (Smith and Morrison 2005). The Census Bureau is a centralized repository for data, whereas each municipality keeps the information contained in small-area datasets separately. Further, they are often tracked and located in the records of several different organizations and government agencies within a community.

The high resolution of small-area datasets means an increase in the number of records and amount of detail over more aggregated information. The City of Austin building permit datasets contained dozens of attributes, including information about the owner and builder, timing of the permit, square footage, valuation and number of units in the proposed building. Census blocks, by contrast contain little physical housing data, recording just five features beyond location (U.S. Census Bureau 2011b). However, the greater detail also means that there is more potential for error in the permit data. Errors will affect data quality more severely for small areas than they will for larger ones due to the difference in sample size (Smith and Morrison 2005).

There is resistance to developing smaller area datasets, much of which relates to privacy and accuracy concerns. The results of small-area analysis could potentially exacerbate spatial sorting, increasing the occurrence and effects of social shifts such as the marginalization of minority groups. These concerns rise from the idea that widely used neighborhood indicators would be developed from small-area analysis, and that such detailed demographic and economic data may cause people to stereotype neighborhoods (Coulton 2008). Economic researchers are also concerned that analysis on such a micro level could cause businesses to more narrowly target profitable markets and bypass areas in need of services and economic stimulus (Coulton 2008).

2.5 GIS and Small-Area Data Mapping, Visualization, and Analysis

As technology has improved, GIS has gained credence in the planning and policy-making fields as a useful tool for assessment and decision-making. More and more local government agencies are hiring GIS specialists and community groups are using GIS maps in their advocacy work to educate and influence people's decisions. GIS has advantages over conventional analysis methods because it features integrated data sources, spatial analysis and modeling capabilities. Though spatial projection and visualization systems, particularly GIS, are useful planning tools, accurate small-area data is necessary for these tools to be effective and in order for them to continue to evolve (Sawicki and Flynn 1996, Farmer 2005).

GIS analysis has been used extensively with geocoded data, where information is matched to addresses. Being able to associate information with a specific address allows researchers to identify and visualize the characteristics of a parcel. Additionally, this allows for more comprehensive analyses of various geographic areas such as blocks, neighborhoods and municipalities through the use of spatial aggregation techniques.

Tables and graphs representing small-area data can provide a sense of a neighborhood's makeup and development trends, but visualization tools take it a step further and allow planners to identify specific locations of vacant lots, for example, the relationship between locations, and the distribution of development across defined neighborhoods. Techniques such as density surfaces and hot spot analysis are popular GIS methods used to visualize and analyze data distributions.

The American Planning Association (APA) recognizes the capabilities of both GIS and small-area datasets to help planners perform their roles better. The APA initiated the Growing Smart project in October of 1994, promoting the use of these resources. The *Growing Smart Legislative Guidebook* that resulted from this project in 2002 lauded GIS, noting that it "is increasingly viewed as a transforming technology and a tool to democratize data" (APA 2002: 15-3). The report provides examples of how GIS has been and could potentially be helpful to government and communities in planning. The report also discusses the establishment of the Geographic Information Advisory Board, which is responsible for promoting the consistency of data elements statewide (APA 2002).

Additionally, the chapter on "Public Records of Plans, Land Development Regulations and Development Permits" (APA 2002: 11) addresses local data sources directly, outlining suggestions including indexing land use and development information by parcel instead of by owner's name with GIS. This would not only make the data easier to use and cross reference, but would also eliminate many of the privacy concerns associated with identifying property by the owner. One section of the report (APA 2002: 15-15, 15-16) calls for uniform forms for use in filing. In a further effort to streamline and standardize records databases, Section 15-201 suggests that any development permit be recorded with the county, either through the recorder of deeds or a similar official. Section 15-202 complements this with the provision that plans and land development regulations apply the same requirements as recordation of deeds (APA 2002).

Much of the literature regarding GIS-based analysis with local small-area data focuses on specific case studies and methods. For example, Jeffery Allen and his team used GIS, parcel and building permit records to predict land use change in a tourism area (Allen et al. 1996). Simon Choi and fellow researchers completed a raster analysis and forecast modeling in Los Angeles focused on household growth relative to transit-oriented developments (Choi et al. 2007). One other study by University of Washington researchers used GIS as an interface to map and view the results of a statistical probability analysis of land cover data in an investigation of growth management policies (Logsdon et al. 1996).

GIS and locally generated small-area datasets are both beneficial to planning efforts and can complement census data and other larger area data. When used together these datasets can be great assets to planners and policy-makers in assessing development trends. This thesis explores the use of building permit records, information commonly collected by most local governments, as a data source for GIS visualization and analysis focused on land development issues. Building permits are not widely used today for this purpose, but offer, with some exceptions, much potential. The thesis argues that building permit records provide both the temporal and spatial detail required to allow planners to understand development trends at the neighborhood level on a continuing basis.

The challenge for using building permit data in GIS is threefold: the datasets have to be accurately mapped, they have to contain attributes that are correctly and consistently recorded, and they have to be of proven and demonstrable use in understanding planning issues, and particularly the responses of private developers and individual land owners to planning initiatives. This thesis seeks to explore these challenges and recommend ways to structure and incorporate building permits into a locality's ongoing GIS mapping and analysis efforts. It will test the use of a continuous record of building permits from Austin, Texas, for exploring three different planning-related trends the city has experienced in the last 20 years.

Chapter 3 Methodology

My investigation utilized municipal records to explore how small-area datasets and spatial analysis tools, specifically building permits and GIS, may be used to study land development. In order to assess the effectiveness of this analytical method, I performed a comparative analysis with municipal data and information gathered from the U.S. Census Bureau, a primary source for many planning and policy related studies. Additionally as part of this study, I evaluated programs and changes related to development to demonstrate potential uses of this municipal small-area data. Finally, based on these analyses, I made recommendations related to the use of building permit data for studying land development. My recommendations included a standardized database template to make building permit records more widely usable.

3.1 Study Area

I set three criteria as necessary conditions in selecting a study area to explore building permit data on a neighborhood scale. The area had to have:

1. Significant and recently demonstrated change in development trends,
2. Suitable initiatives or conditions related to development that could be used as case studies, and
3. Available, relevant datasets.

In applying these conditions, I identified the City of Austin, Texas, as an appropriate location and subsequently set it as the context for this study. The city has experienced rapid growth over the past few decades, and was specifically identified as having the third fastest growing population of large U.S. cities from 2002 to 2006 (Christie 2007). Concomitant with this growth, two city initiatives aimed at directing development have been undertaken: the Smart Growth Initiative (SGI) which was official city policy between 1998 and 2008 (Austin City Connection 2010), and the conservation efforts of Austin's Wildland Conservation Division including the Balcones Canyonlands Conservation Plan (BCCP), begun in the 1990s (The Nature Conservancy 2010). Related to the city's development trends and growth control initiatives, gentrification has affected change in several neighborhoods and drawn attention to demographic shifts throughout Austin (Wilson et al. 2007). The SGI project, conservation efforts, and presence of gentrification offer appropriate case studies for this exploratory research in spatial analysis and visualization. Finally, Austin has a comprehensive record of building permits from 1990 through 2009. The two-decade span allowed some general trend analysis and covered the time period directly applicable to the case studies identified above. These records were also publicly available and accessible in spreadsheet and GIS shapefile formats on the city's website.

3.2 Datasets

The primary dataset for this study was City of Austin building permit records for 1990 through 2009 (City of Austin n.d. a, City of Austin n.d. b). From the raw data I extracted new residential and residential renovation permit records to perform my analyses.

I obtained additional data records from the City of Austin and the U.S. Census Bureau that I used to provide context, perform comparative analyses and demonstrate usage of the primary dataset. These datasets included:

- Building Permit and Census comparative analysis
    - U.S. Census American Community Survey housing data 2004–2009 five-year estimates (U.S. Census Bureau 2011b)
    - U.S. Census decennial census housing data 1990, 2000 and 2010 (U.S. Census Bureau 2011b)
    - U.S. Census boundary data for census tracts (U.S. Census Bureau 2011b)
- Case studies
    - SGI Desired Development Zone boundaries (City of Austin 2010)
    - Balcones conservation parcel boundaries (City of Austin 2010)
    - U.S. Census decennial census data on population, race, housing units, housing units year built, housing units median year built (U.S. Census Bureau 2011b)
- Base data
    - City and county boundaries (City of Austin 2010)
    - Political jurisdictions (City of Austin 2010)
    - Zoning and parcel maps (City of Austin 2010)
    - Transportation networks (City of Austin 2010)
    - Land use (City of Austin 2010)

3.3 Building Permit and Census Comparative Analysis

The first part of my study was a review of housing related data from the Census Bureau and comparison to Austin's building permits. I used three census products in my comparative analysis. **Table 1** summarizes the primary characteristics of these products relevant to my research.

Table 1 Census Database Summary Characteristics

	Censtats Building Permit Database	Decennial Censuses	American Community Survey
Data Source	• Local and state municipalities	• Survey of all U.S. residents	• Survey of selected U.S. residents
Relevant Data Fields	• Total permit counts • Total number of units permitted • Total construction costs • Residential permit categories o Single-family o 2-family o 3 and 4-family o 5 or more family	• Total housing units	• Year built 1990-1999 • Year built 2000-2004 • Year built 2005-2009 • Median year built
Frequency and Time Period Used	• Monthly - 2000 through 2009 • Annually - 1996 through 2009	• Once per decade – 1990, 2000, 2010	• Annually for 1, 3 and 5-year estimates – 5-year estimate for 2004-2009
Geographic Units	• Place (select cities, towns and unincorporated areas) • County	• Block • Block group • Tract	• Block • Block group • Tract

3.3.1 Censtats Building Permit Database

The Censtats Building Permit database is a product of the U.S. Census Bureau that reports specifically on building permits. The database can be viewed and searched by following the "Permits by County or Place" link located here: http://www.census.gov/const/www/permitsindex.html (U.S. Census Bureau 2011c). As this information is collected from cities and other municipalities, I compared it to the data contained in Austin's records to assess consistency and accuracy, hypothesizing that the data would be very similar. However, as the Bureau releases the permit data only by place and county, this source was not useful for the small-area spatial analysis within a city that I focused on in this thesis.

3.3.2 Decennial Census

Decennial census data is collected via a mail-in form that is sent to all American households. The Census Bureau makes a great effort to ensure a small sampling error in this survey by employing representatives to conduct follow-up interviews by phone and in-person for residents who do not respond to the mailed form. Though the percentage of households that participate in the decennial censuses is high, the data collected is not as detailed as that found in the Bureau's American Community Survey, as explained in the "Literature Review" in Chapter 2.

In my research, I assessed the three sets of decennial census data most relevant to my study time period, those done in 1990, 2000 and 2010. I determined that the variables showing the number of housing units constructed for specified time periods was the census data most applicable to my study. However, the 2010 Census did not include these variables since the decennial Census no longer uses the so-called "long form". This information is instead gathered and reported as part of the ACS. Therefore, in order to assess the decennial census, I looked at a different piece of data: total housing units. I used GIS software, ArcMap, to calculate the difference in total housing unit numbers for each census tract from 1990 to 2000 and from 2000 to 2010. With these maps, I attempted to show the basic trends in residential construction through recent decades, expecting that they would illustrate a consistent growth in housing units.

3.3.3 American Community Survey

The Census Bureau distributes the ACS to approximately three million households every year (U.S. Census Bureau 2011a). As it has a smaller sample size than the decennial census, it has a greater margin of error. The ACS is a survey covering information on topics such as demographics, education, economics and housing. The resulting data is based entirely on the responses of residents, increasing the margin of error. For example, the second question under "Housing" asks when the housing unit was constructed (U.S. Census Bureau 2011a). Because the resident completes the survey as opposed to the builder or owner, their response is likely to be less informed, especially if they are renting the unit. For this reason, I expected the accuracy of the ACS housing data to be lower than that of Austin's building permit records. Note that though this survey method introduces potential error in comparing Year Built responses with actual records, this limitation is not unique to the ACS as the same data collection method was used to report the results of the "long form" in the 1990 and 2000 decennial censuses.

For my study, I used data from the ACS 2004 to 2009 five-year estimates. The primary data fields I analyzed were those indicating the number of housing units built within defined time periods. The periods relevant to my work were

1990 to 1999, 2000 to 2004 and 2005 to 2009. As Austin's building permit records included information on the year each permit was issued, I was able to group this data based on the time periods used by the ACS and aggregate these files to census tract geography to do a direct comparison of ACS and building permit data. I compared the ACS year built data to Austin's year permitted data in three different ways. I created a series of separate maps for the two datasets to provide a side-by-side comparison. Additionally, I determined the differences between the ACS and city housing counts and showed these results in a single map for each time period. The final perspective I created of this information was a series of maps illustrating the differences between the datasets and indicating which dataset had the larger or smaller counts for each tract. I anticipated that there would be discrepancies in the data as the ACS recorded year built while Austin's data resulted from permits issued. I also expected differences due to the small sample size and resulting margin of error of ACS data described above. Finally, I hypothesized that the city's building permit database would show higher numbers as it was possible that not all of these permit structures were constructed.

3.4 Case Studies: Austin's Growth Issues 1990 to Present

In my research, I used three case studies to demonstrate how a spatial assessment of growth and development change issues can be done using building permit records in varying scenarios. I analyzed the Balcones conservation project and Austin's Smart Growth Initiative as examples of proactive and explicit land use decisions. Conversely, shifting neighborhood demographics and gentrification provided a scenario for studying the changes that have resulted from residential mobility decisions.

3.4.1 Balcones Canyonlands Conservation Plan

Environmental conservation programs are initiatives aimed at directing growth and development. A primary initiative under Austin's Wildland Conservation Division is the Balcones Canyonlands Conservation Plan (BCCP).

The U.S. Fish and Wildlife Service officially recognized the BCCP in May of 1996 after several years of planning and land acquisition efforts (Travis County, Texas 2010). The plan was a regional effort initiated by the U.S. Fish and Wildlife Service and the City of Austin and Travis County to protect a variety of wildlife species and preserve their habitats. The Balcones Canyonlands Preserve (BCP) was established within the Bull Creek Watershed under the BCCP. Along with several other partners including the Nature Conservancy, the BCP was to be a series of preserves totaling a minimum of approximately 31,000 acres. The Nature Conservancy worked with the City of Austin to expand the preserve by 14,000 acres in the 1990s (The Nature Conservancy 2010).

In my review of the BCP using building permit data, I focused on exploring the relationship between development and the designation of preserve lands using two methods of spatial analysis. Before creating any maps, I separated the permit data into six files based on the years that permits were issued in order to be able to assess trends over time. The first series of maps I created were raster density surfaces depicting permit data in Austin in relation to the location of the conservation lands. The use of raster density maps enables the visualization of generalized patterns of development comparable at different time periods, and is meant to show "hot spots" of development and their shifts through time. The second analysis I performed used multi-ring buffers and spatial joins to determine the number of permits within set distances of the conservation land boundaries. I expected my analysis to illustrate information on the concentration and dispersion of residential development in relation to the BCP. I also intended to demonstrate how data on the size and value could be organized into spatial categories for analysis.

3.4.2 Smart Growth Initiative

When, in the late 1970s, Portland, Oregon and other cities across the country were experimenting with urban growth boundaries and other methods to address their rapidly growing and sprawling populations, Austin was content as a growing, but relatively quiet state capital and college town (Tu et al. 2005). It was the 1990s when Austin's identity as a small college town was overtaken by the abundance of technology companies that established themselves in the city, bringing the nickname "Silicon Hills" to the area (Tu et al. 2005). By 2006, Austin was the third fastest growing large city in the nation (Christie 2007).

City officials and planners recognized the shift in growth trends in the 1990s and devised the Smart Growth Initiative (SGI) in 1998 to address the city's needs related to growth and development. Austin's plan had three primary incentive categories: the Smart Growth Matrix Incentives, Primary Employer Incentives and SMART Housing Incentives (Safe, Mixed-Income, Accessible, Reasonably-Priced, Transit-Oriented) (City of Boulder, Colorado 2011).

The Smart Growth Matrix was a tool of the City of Austin Transportation, Planning and Design Department used for assessing development proposals within Desired Development Zones (DDZs). These DDZs were areas identified and designated by city officials and planners as neighborhoods where future development should occur. Three smart growth goals were measured through a series of questions regarding a proposed project. The goals were:

1. Determine how and where development occurs.
2. Improve quality of life.
3. Enhance the tax base.

Points were given to projects based on criteria such as the proximity of the development to public transportation, the proposed use and density, environmental impacts and urban design elements. Depending on the aggregate score of a project based on the criteria matrix, incentives may be approved for the development. These incentives could include the waiver of 50% to 100% of fees imposed by the City of Austin that would be applicable to the project. Additionally, if the proposal met enough of the City's Smart Growth goals, an agreement or partnership with the developers and the City of Austin could be established to improve related infrastructure. Examples of this include investment by the city to update water and wastewater lines and add sidewalks (City of Boulder, Colorado 2011).

Despite its sustainability goals, the SGI was criticized for being discriminatory. Though it appeared to be an initiative with only admirable intentions of conservation and concentrated development to increase the efficiency of municipal services, it encouraged intensive development that some residents found detrimental. The Smart Growth Matrix incentive program was stopped in 2003 (City of Boulder, Colorado 2011) and the entire initiative ended in 2008 (Austin City Connection 2010).

The demonstration of building permit analysis with the SGI, in this thesis, involved visualizing changes through time, which I accomplished by creating raster files for individual years and aggregating or subtracting them. I also performed spatial joins of building permit data to the DDZ boundaries to illustrate how a comparison of development within these areas versus development in the entire City of Austin over time could be done.

3.4.3 Gentrification

Gentrification is one example among many of ways that neighborhoods change in their social, economic and demographic makeup. Frequently, gentrification is associated with renewal and increased vibrancy in poor neighborhoods. Though positive changes to a gentrifying community can also have the effect of displacing lower income residents. Gentrification is a form of neighborhood change that has drawn a lot of attention in Austin.

East Austin is an area that has long been home to racial and ethnic minorities. Planners in the late 1920s, taking advantage of the Jim Crow practice of segregated schools and other facilities, further encouraged minority residents to relocate there by putting these facilities for them only in the eastern part of the city (Wilson et al. 2007). Interstate Highway 35 was constructed in the early 1960s between the central downtown area and East Austin, adding an imposing physical barrier to the already segregated city. Within the last 20 years from the late eighties through early 2000s, however, East Austin has seen a shift in its demographic makeup as higher income residents have discovered the affordable living and work spaces close to downtown (Wilson et al. 2007).

Though the renewed interest in and attention on East Austin brought new services and opportunities to the area, it also threatened to price out much of the neighborhood's existing population (Wilson et al. 2007). Within just six years, from 1999 to 2005, the median sales price of houses in Central East Austin more than doubled, increasing from $58,000 to over $119,000 (Wilson et al. 2007). East Austin became an attractive place for both commercial and residential construction and the groundwork for gentrification was laid.

Throughout most of my study, I reviewed new residential building permits. Though a primary category for analysis, building permit databases often contain records related to other uses, such as commercial and industrial, as well as different types of construction, such as additions, rehabilitation and demolition projects. For the purpose of reviewing the case of gentrification, I decided to use a subset of the building permits including only those for renovation. I made this choice as gentrification involves rebuilding and renovating by definition. I used raster density surfaces to show patterns of renovation work over time in Austin. I then focused in on areas of high concentrations of permits downtown and created time series maps illustrating renovation permits as point data, density surfaces and aggregated by census tract. Also, I mapped census data attributes traditionally used to indicate gentrification, by census tract, to allow for correlations. I hypothesized that renovation work was an indicator of gentrification. My intention was to show the relationship between permit and census data and how the small-area dataset might be used to gauge gentrification and neighborhood change on a more detailed scale and more frequently than census indicators.

Chapter 4 Building Permit and Census Data Issues and Limitations

In order to perform the evaluations that this thesis is focused on, I had to research municipal data itself, its accessibility and composition. Additionally, it was necessary to look closely at census housing-related data as the Census Bureau is a primary accepted source of land development information, and it was important to draw comparisons between this data and building permit records. This chapter describes the challenges and limitations of building permit records as a GIS data source, and of census data in assessing local land development.

4.1 Building Permit Challenges

The first challenge in working with municipal building permit data is finding it. Though all municipalities record building permits, the records systems vary greatly between places, and they are not always readily available to the public. Austin, Texas, has some of the most comprehensive and accessible building permit data found in this study with over 20 years worth of permit records publicly available on the city government website in multiple formats including spreadsheet, portable document and GIS shapefile.

In my search of municipal websites, I found varying levels of permit records availability. The city of Boston, Massachusetts, for example, has a searchable online database of building permits issued within its jurisdiction. Multiple criteria can be used to search the database, including a date range. For permits issued starting December 15, 2009 search results can then be downloaded to an Excel file, however this can only be done for 200 records at a time. Additionally, the information for permits until December 15, 2009 can only be viewed on the website and minimal information is included in the chart displayed. Instead each record has a scanned copy of the permit application attached (City of Boston 2010). Boston provides an example of a dataset that, though accessible, is not easily navigable and does not lend itself easily to a comprehensive study of records. It is more suited to users looking for information on a specific parcel or small set of parcels with common characteristics. This is similar to the records of many other cities and towns including New York City with its online Buildings Information System (The City of New York 2012).

However, there are also many municipalities that do not provide any permit information online. This data must be requested from the municipal government. The City of Dallas, Texas, for instance, directs individuals to go to the Building Inspections Library of Records or, alternatively, to submit an Open Records Request by email or mail in order to obtain local permit information (City of Dallas, Texas, 2001-2006).

The second obstacle in working with building permit records is the inconsistency of the data. This includes inconsistencies between municipalities and over time. During the course of this research, I considered Travis County records as a potential resource to expand the geographic area that would be analyzed with GIS. This data proved to be difficult to incorporate into the study however, as the records were not compatible with those of the City of Austin. The posted Travis County database only included records from 2003 to 2010. Records for previous years need to be requested from the county government. Additionally, the county data was not as detailed. Much of the pertinent information utilized in this study, including the valuation and square footage data fields were not available in the Travis records, as they were in Austin's database.

Even within Austin's records, there were changes and inconsistencies in the data recorded over time. From 1990 to 1994 only new construction permits were recorded, whereas from 1995 to the present, information on demolitions, additions, remodels and renovations were included in the building permit database. Additionally, sign permits and stand-alone trade permits issued for small projects permitted without plans such as electrical, plumbing, mechanical and gas piping work, were all included in the records from 1995 through February, 2007.

In addition to changes in the records kept, there were also changes in the information recorded. In some cases, attribute fields were changed annually. Throughout the 1990s the records were consistent in attributes. However from 2000-2007, the list of features included in the dataset changed every year except for 2002 to 2003. The most notable change though was when the records database was upgraded in March of 2007 and the entire system went from a product named PIER to an alternative database format know as AMANDA. Most of the existing attributes and codes used remained the same. However, the number of attribute items recorded increased from a maximum of 39 to 59 items.

The third major challenge in working with building permit data is the completeness of the dataset. During the data cleanup process, it was necessary to eliminate some of the data from analysis due to missing information. I removed records with "unknown" or "N/A" permit types. In some cases, fields were simply blank, or zero values were recorded for number of units, square footage or valuation. These records were not removed from the analysis dataset as I decided that it was more important to my study to include the information that was available, rather than eliminating an entire record due to a missing field value. This is discussed further in the next chapter, "Analysis of Building Permit Data Quality and Cleanup Process".

4.2 Census data challenges

In this study I used tract level data when analyzing information from the U.S. Census. The census variables used in the analysis were:

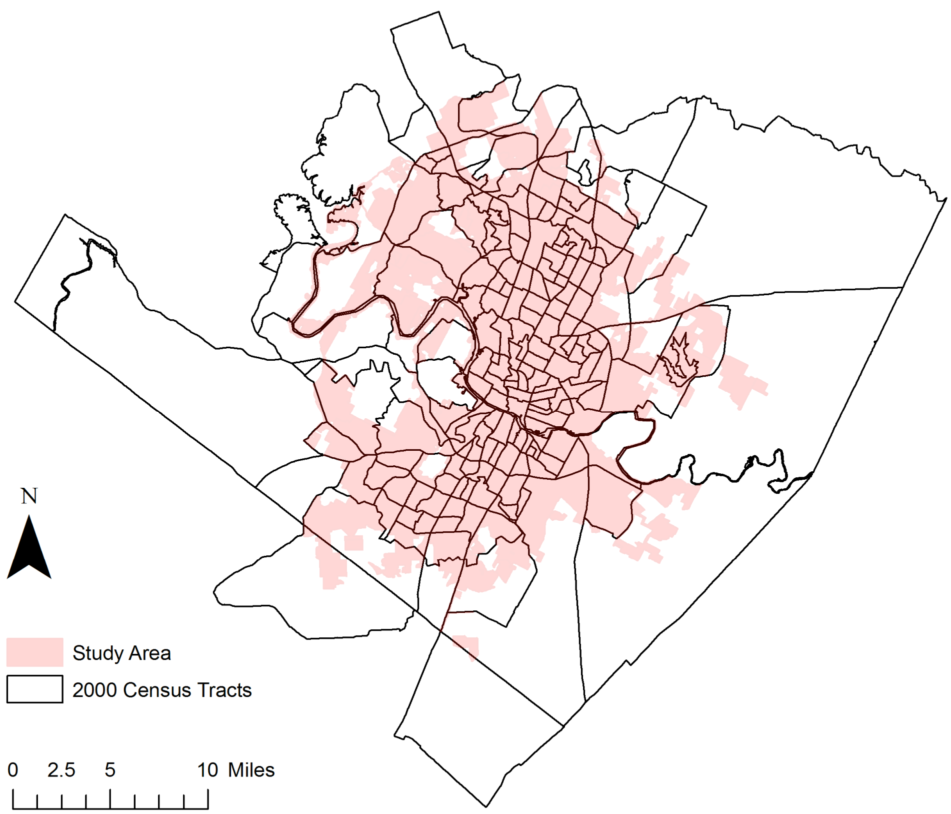
- Total number of housing units
- Year housing units were built
- Median year housing units were built
- Total population
- White population
- African American population
- Hispanic population

Though of lower resolution (and thus less nuanced at the local level) than block group geography, it was necessary to use tracts in this analysis for consistency. Housing data relevant to this research is available at the block level, the smallest census unit, for the 2000 and 2010 decennial censuses. However, the 1990 decennial census had this same information measured only at the block group and tract levels. Further, in order to download the 1990 block group data from the Census Bureau's website, it was necessary to download it by tract and tracts are grouped by county. This means that each of the 189 tracts in Austin would have to be identified from the 241 tracts – based on the 2000 decennial census geography divisions – within Travis, Williamson and Hayes Counties and each tract would have to be manually added to the output selection in order to obtain the data for all block groups within Austin (U.S. Census Bureau 2011b).

Additionally, only the 2010 Redistricting Data was available as of June 2011 and it was still in a format that proved impossible to process for an area the size of Austin as the data had not yet been organized into standard census geographies below the county level (U.S. Census Bureau 2011d). Tract level geography shapefiles and data files are available on American FactFinder, the Census Bureau's primary site for data downloads in a format that is much simpler to use. Since my analysis was performed, data access methods have improved considerably.

Working with census tracts also proved challenging because the boundaries of the study area meant that there were several tracts that fell partially within the study area and largely out of it. The study area is defined by Austin's official City Limits. This is illustrated in **Figure 1** as you can see that the shaded space indicating the study area does not match the black lines outlining the census tract boundaries. This issue is observed often in research using census geography and various methods have been developed to address the discrepancy. One of the most widely used methods is areal weighting. Areal weighting takes data within a zone (e.g., population counts) and assumes a uniform distribution of this data. It then reallocates the counts based the proportion of the zone lying within the area of interest (Sadahiro 1999). Thus, if the Austin city limits passes through a census tract that has a population of 5,000 people, and 20% of the tract is within Austin, the areal weighting method would assign 1,000 people to Austin, and 4,000 to the neighboring area. However, the assumption of uniform distribution is not a valid one. Thus for the purposes of this study I chose to perform the spatial analysis without adjustment to the data for this boundary issue which would simply introduce further error.

Figure 1 Census Tracts Intersecting Study Area



Another challenge I discovered when working with census data from multiple decennial surveys relates to changes in the geographic unit boundaries. The boundaries of census tracts are drawn based on political divisions, but also considering population sizes. Each tract is sized to contain a population within the range of 4,000 to 8,000 individuals. As populations have grown and shifted, census geographies have been divided to maintain the average population sizes within them. Additionally, mapping technology has become more precise and therefore the boundaries have shifted over time as boundary lines like roads have been represented with higher positional accuracy.

In my research, I used the 2000 census tract boundaries as the basis for all census information and comparisons. The 2000 decennial data as well as the ACS 2004-2009 data used these borders. For the 1990 decennial data, I used the Census Geolytics Neighborhood Change Database (NCDB) that helps to mitigate the issue of changing census boundaries by allowing users to normalize 1990 census data to 2000 census tract geography within the program. The 2010 decennial census data was more difficult to adjust. In order to tie the 2010 information to the 2000 geography used to organize the rest of the census data in the study, I had to perform a spatial join. I first converted the polygon features of the 2010 census information to centroid[1] points, so that all of the information associated with each polygon was now associated with a point located in the middle of the polygon. Once this step was complete I was able to perform a spatial join of these points to the polygons of the 2000 census tract data, specifying that the numeric attributes of the 2010 data be summed. In this way, the data for each field was aggregated when there was more than one 2010 point located within a 2000 polygon.

[1] "The geometric center of a feature. For line, polygon, or three-dimensional features, it is the center of mass" (ESRI 2012).

The data limitations described in this chapter affected the boundaries, specifications and direction of this study. They are all issues that should be considered when undertaking an analysis using this information.

Chapter 5 Building Permit Data Quality and Cleanup Process

In this chapter, the format and relevant components of Austin's building permit records are described along with the analysis that I did of the dataset itself before using it to explore land development issues. In order to analyze the building permit records with GIS, I first had to review and clean up the database. That cleanup process involved determining the data to include in my final work file and justifying why the chosen elements are useful to my research.

I downloaded the municipal building permit data used in this analysis from the City of Austin's FTP and Growth Watch websites. The city has several pages of GIS data available to the public including permit records, geographic features, hydrology, infrastructure and assessor's data.

I was primarily interested in permit data that spanned the twenty-year period from 1990 through 2009. However this data was located in several different files. The Growth Watch data server (Austin City Connection 2010) had a separate file for each year of permit records. Austin's FTP sites had files that contained multiple years of records, though none encompassed the entire two decades of the study (City of Austin 2010). Therefore, I aggregated the information from three separate files on the web server. The first was the largest, containing permit records from 1990 through February 2007. The second file had records from March 2007 through September 2009, and the last had the full year of 2009 permits. Administrative changes, including transitions to new database formats, likely explain the separate files.

By aggregating the data from these three files, and removing all duplicate records caused by overlap, I created a file of permit records for the twenty-year period from 1990 through 2009. An initial assessment of this file provided a total permit count of 211,368 with 77,284, or 37 percent of these permits being issued for new construction purposes, the main category of my focus on land development. In addition to reviewing a summary of all of the database records, I also broke the counts down by individual year. In looking at the summary statistics and comparing the annual changes, it was clear that large differences existed in the data records for each year. For example, the minimum number of permits recorded was 1,052 in 1990 while the maximum was 26,254 in 2006. I concluded that these wide spans likely indicated differences in the data recorded as opposed to being entirely attributable to changes in development patterns and construction behaviors. Therefore, before performing a spatial analysis, I reviewed the data and cleaned it up to make sure it was comparable and consistent across years.

I identified three central characteristics necessary to address for consistency: permit type, status and location.

5.1 Permit Type

Permit types that were found in the database include:

- new construction
- demolition
- remodel
- addition
- renovation

- repair
- driveway
- relocation
- unknown
- N/A
- shell
- sign
- stand-alone trade

In reviewing the permit type category, I discovered three primary inconsistencies in the data. The first was that only new construction permits were recorded from 1990 through 1994. Additionally, permits for signage, and stand-alone trade permits issued for small projects without plans such as electrical, plumbing, mechanical work and gas piping, were included in the records from 1995 through February of 2007. Finally, the "shell" category used to designate the initial frame of a project was a new category as of 2007.

A summary of the permit types within the database is shown in **Table 2**. As part of the data cleanup, I eliminated "shell", "stand-alone trade" and "sign" permit records, as well as those categorized as "N/A" or "unknown". I retained a data file with demolition, remodel and move/relocation types even though this information wasn't recorded until 1995, as this information would allow me to review subsets of the data for specified periods of time for the case studies. In order to make the data comparable across the entire study timeframe however, I refined the primary dataset further to include only new construction permits.

Finally, I chose to look specifically at permits categorized as "residential". Therefore, the primary dataset I used consisted of permits for new residential construction.

Table 2 Summary of Permit Types in Initial Dataset 1990 to 2009

	Totals	Minimum	Maximum	Average	Median	Standard Deviation
Permit Counts						
Total permits	**211,368**	1,052	26,254	10,568	11,194	6,902
New construction	**77,284**	1,052	6,158	3,864	4,175	1,398
Demolitions	**4,239**	0	661	212	134	236
Remodels	**63,174**	0	7,484	3,159	3,647	2,268
Move/ Relocations	**916**	0	136	46	44	42
Shells	**153**	31	68	51	54	19
Unknown	**57**	0	28	3	0	8
Stand-alone trade permit	**55,183**	0	12,727	3,066	1,782	3,907
Signs	**10,276**	0	1,404	571	691	454
#N/A	**86**	0	74	5	0	17

5.2 Permit Status

A review of the permit status category also showed differences in what was recorded over the years. There were a total of seventeen statuses used to categorize permits from 1990 to 2009, however the only three consistent statuses across the two-decade span were "Active", "Final" and "Pending". Additional categories included "Dormant", "Expired", "Withdrawn" and "Void" among others. For records consistency, and also because my goal was to reduce the chance that permits analyzed were not used, I pulled only those permits with an "Active" or "Final" status for my analysis.

5.3 Spatial Location

The final piece of criteria that I assessed was the location of the permits. All were within Austin's jurisdiction; however, the city's boundaries are defined in a few different ways. Austin's official City Limits include two types of areas: Full Purpose Jurisdiction and Limited Purpose Jurisdiction. The differences between these two designations relates to the applicability of City services, taxes, ordinances and regulations. Besides these areas, there is the Extra-Territorial Jurisdiction (ETJ), which extends five miles beyond Austin's City Limits and is subject to a subset of the city's regulations (Austin City Connection 2011). For my study, I chose to use Austin's City Limits including both the Full and Limited Purpose Jurisdictions. Permits were issued outside of these areas though, which meant that when the permits were uploaded to ArcMap, several of the points fell outside of these boundaries. Therefore I eliminated these permits based on spatial location.

5.4 Final Analysis File

The clean larger dataset containing information on new construction, renovations, relocations and demolitions for commercial, industrial and residential uses had a total permit count of 137,348, meaning that 74,020 permits were eliminated from the raw data files I began with.

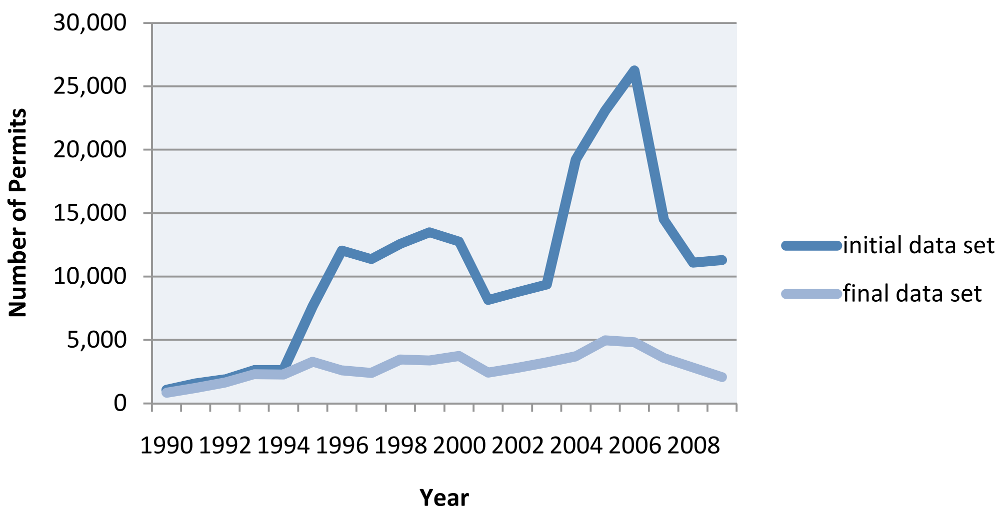
The primary dataset that I identified and used in my census comparison analysis fit the following criteria:

- permit issue years: 1990-2009
- permit status: active or final
- permit type: new

- permit usage: residential
- location of permit: within Austin's Full or Limited Purpose Jurisdiction

This dataset contained a total of 57,591 records. In reviewing the annual permit counts and characteristics in this file, there is greater consistency across the years than there was in the raw data. One example of the data consistency change between the initial and final analysis datasets is illustrated in **Figure 2**.

Figure 2 Building Permit Counts in Initial and Final Analysis Datasets 1990 to 2009



Once my data was cleaned up, I identified the permit characteristics and data elements most useful for my research. The primary elements were number of housing units, project size and project valuation.

There was missing data throughout the database. Therefore I assessed the categories I planned to analyze in order to make sure that the data was complete enough to use. To do this, I determined the percentage of records that had missing or zero data in each field. **Table 3** below shows the percentage of overall records with missing information was one percent or less for each of the characteristics assessed. Based on this I decided not to eliminated any records in the primary dataset due to missing information, as I determined that including the available information in the record was more important than eliminating a record for a missing field. I concluded that the one missing field would have less of an impact on the overall analysis than eliminating an entire record. Though I included these for the overall spatial analysis, **Table 3** shows summary statistics both where the zero values were included and also where they were excluded.

I had performed this analysis on the raw dataset and at that point determined that many of the records with seemingly missing information were actual zero values as they were attributed to demolition or repair records.

One final data challenge that I addressed related to the building permit records was the adjustment of the valuation data. There are many outside factors that affected the building permit records over the years, but one that could be controlled for is inflation. Using historic inflation rates calculated from the Consumer Price Index I adjusted the valuation information based on the year of record so that all numbers were in 2009 dollars (InflationData.com 2011). By performing these adjustment calculations, I mitigated the effect of inflation on the data and made the valuation information more directly comparable across years. This adjustment is reflected in the data displayed in **Table 3**.

By assessing the data available for my study, I was able to refine the building permit files to properly fit the scope of my research. The data evaluation and cleanup also helped me to determine limitations that the data itself might put on my work. The process made me aware of missing information and record inconsistencies across years, as well as allowing me to mitigate the effects of these issues.

Table 3 Primary Dataset of New Residential Construction Permits 1990 to 2009

	Totals	Minimum	Maximum	Average	Median	Standard Deviation
Permit Counts						
new residential construction	**57,591**	834	4,968	2,880	2,818	1,056
Units						
total units	**122,338**	842	11,163	6,117	6,222	2,708
total average units/project	**2.12**	1.01	3.41	2.07	2.04	0.57
records missing unit data	**197**	0	77	9.85	0	19.12
percent of records missing unit data	**0.34%**	0.00%	2.15%	0.29%	0.00%	0.54%
average units/project excluding records with missing unit data	**2.12**	1.01	3.41	2.06	2.04	0.56
Area						
total sf recorded	**243,824,614**	2,711,128	19,479,047	12,191,231	11,982,424	4,911,498
average sf/project	**4,234**	3,190	5,437	4,161	4,069	628
records missing area data	**147**	0	30	7.35	6	7.85
percent of records missing area data	**0.26%**	0.00%	0.84%	0.25%	0.18%	0.23%
average sf/project excluding records with missing area data	**4,245**	3,190	5,482	4,172	4,077	635
Valuation						
total valuation recorded ($)	**10,298,797,411**	97,045,994	1,164,710,418	514,939,871	480,379,457	259,200,688
average valuation/project	**178,827**	114,845	325,066	173,357	161,690	54,215
records missing valuation data	**597**	0	117	29.85	24	29.71
percent of records missing valuation data	**1.04%**	0.00%	3.58%	1.01%	0.87%	1.00%
average valuation/project excluding records with missing valuation data	**180,700**	115,125	327,995	175,063	163,371	54,326

Chapter 6 Results and Analysis

This chapter demonstrates the use of building permits to enhance understanding of land development continuously on a neighborhood level. There were two main components of the analysis, which are described here. The first was an evaluation of building permits in relation to census data. This was done to assess how comparable the data sources were and in what way they could prove complementary. In the next section, I used examples of development-related issues as case studies to illustrate visualizations and analyses that can be completed using building permit records with GIS. Utilizing the characteristics of building permits, including information on size, construction valuation and number of units, I showed residential development locations and patterns in relation to conservation lands, designated smart growth zones and known areas of gentrification.

6.1 Building Permits and the U.S. Census

In comparing census information with Austin's building permit records, I looked at three different census products. The first being the Censtats Building Permit Database, the second being the Decennial Census and the last was the Bureau's newest survey, the American Community Survey (ACS). A table summarizing the primary characteristics of these data sources that I used in my research can be found in the "Methodology" chapter.

6.1.1 Census Building Permit Database

The U.S. Census maintains a database of permit records for new privately owned residential buildings for the entire nation. The lowest level of aggregation is by town or city, thus these data cannot be used to explore patterns across a city. However, I thought it important to compare total permit counts from the census with Austin's records to establish a rough basis for comparison. The Census Bureau's database is a collection of information from local and state municipalities and includes data on total permit counts, number of units and construction costs. Additionally the residential permits are broken out into categories of single-family, two, three and four, and five or more family houses. (U.S. Census Bureau 2011c).

This data can be viewed on a monthly basis from 2000 through the present. On an annual basis, records are available from 1996 through the most recently completed year (i.e. 2010). Place and County are the available geographic unit options, with Place being select cities, towns and unincorporated areas.

Table 4 shows a comparison of permit counts and total housing units permitted in Austin. The Census only began collecting building permit data in 1996; therefore a comparison of this information to the primary dataset is not possible for the entire study timeframe. As the Census Bureau gathers this information from local and state municipal offices, it seems reasonable to assume that the data would match or at least approximate the information on record with the City of Austin. We see in the table below that this data is indeed very close in some years, for instance the permit counts differ by just two in 2001.

However, we see a more significant difference in other years, particularly in 2008 where Austin recorded 717 more permits than the Census has in its permit count. In the same year, Austin shows 2,079 more housing units permitted than the Census. These differences might be attributed to various factors. The City of Austin may have provided estimates to the Census Bureau or could have had incomplete information at the time that the Bureau requested the data. The municipal data shown below is from the city's database after my quality review and cleanup. As described earlier, this cleanup included removal of permits with "unknown" or "N/A" permit type descriptions, as well as removal of some permits based on their spatial location. Therefore an additional consideration is that the Census may include some of the records that I removed based on my cleanup and study criteria.

Table 4 Comparison of Austin and Censtats Building Permit Data

	Permit Counts			Housing Units		
Year	City of Austin	Census Censtats	Difference	City of Austin	Census Censtats	Difference
1990	834	-	-	842	-	-
1991	1,226	-	-	1,830	-	-
1992	1,646	-	-	2,396	-	-
1993	2,292	-	-	4,476	-	-
1994	2,282	-	-	5,834	-	-
1995	3,272	-	-	11,163	-	-
1996	2,611	3,021	410	6,049	6,946	897
1997	2,407	2,725	318	5,144	6,298	1,154
1998	3,450	3,834	384	6,701	8,086	1,385
1999	3,393	3,696	303	7,749	8,385	636
2000	3,747	3,855	108	8,615	8,528	-87
2001	2,413	2,411	-2	6,687	6,722	35
2002	2,807	2,802	-5	6,395	6,374	-21
2003	3,234	3,409	175	5,109	5,298	189
2004	3,718	3,855	137	5,867	6,041	174
2005	4,968	5,012	44	9,017	8,794	-223
2006	4,806	4,817	11	8,700	9,265	565
2007	3,583	3,548	-35	10,090	7,771	-2,319
2008	2,828	2,111	-717	6,458	4,379	-2,079
2009	2,074	2,001	-73	3,216	3,539	323

6.1.2 Decennial Censuses

This section provides examples of how development and growth can be tracked with decennial census data. For reasons discussed earlier, this analysis was carried out at the level of the census tract. Using data gathered on the total housing units in each census tract in 1990, 2000 and 2010, I mapped the difference between the counts from 1990 to 2000 and 2000 to 2010. I did this in order to illustrate the change over time tracked by the decennial census. This did not provide information directly comparable to new unit construction, as is evident in **Figure 3** and **Figure 4,** which show decreases in housing units in some tracts.

Figure 3 Change in Total Housing Units Recorded from the 1990 to 2000 Decennial Census

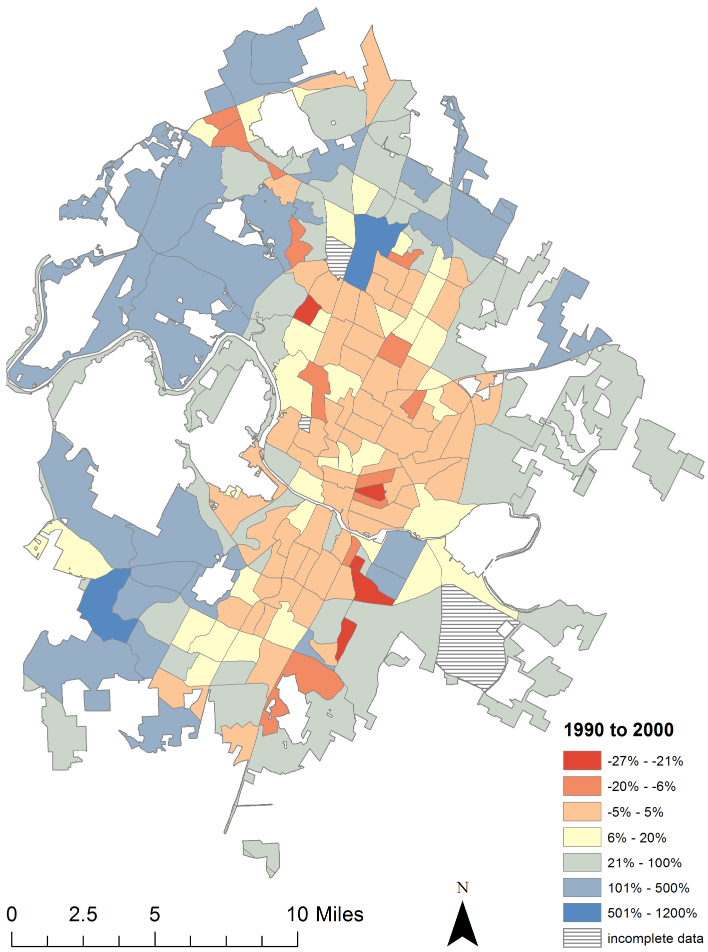
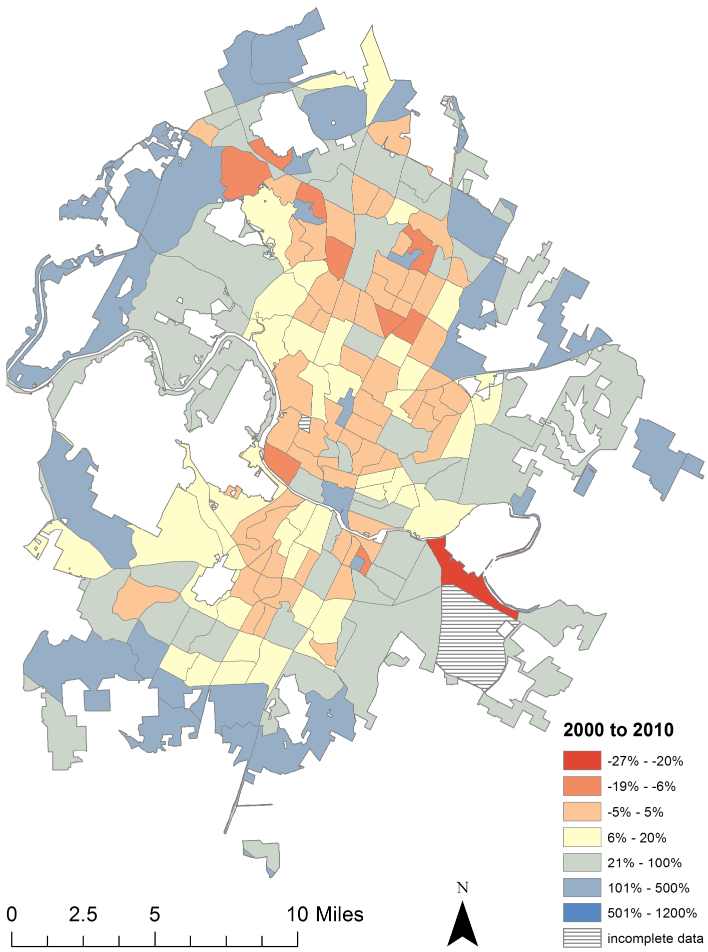


Figure 4 Change in Total Housing Units Recorded from the 2000 to 2010 Decennial Census



I looked for ways to adjust the change in the Census's total housing unit numbers to reflect only new construction and determined that, in theory, I could adjust the municipal new permit data counts by subtracting the demolition permits within the database in order to provide a comparison to the census change data. However, demolition data was not consistently found in the Austin permit records so this hypothesis was not confirmed.

Even without adjusting the data for demolition permits, however, we should still be able to note general development growth trends from the census-recorded change in housing units between decades. Surprisingly however, the total number of housing units decreased in some census tracts. This data could be interpreted to indicate that either no residential homes were constructed during these periods or that housing was being demolished more quickly than it was being built. However, these conclusions were not logical based on permit records and general development trends. Therefore, I considered the possibility that there were errors or discrepancies in the data or in my analysis. The maps show that the largest decreases, as well as the greatest increases, in housing units were seen on the edges of the study area. This indicates that presence of the MAUP issue discussed earlier in Chapter 2. Additionally, the decreases shown on the map could be related to changes in census geography.

6.1.3 American Community Survey

The final piece of my comparative analysis with the census looked at data provided by the American Community Survey. The following maps compare American Community Survey data regarding year of housing construction to the building permit records from corresponding time periods. The ACS breaks this information up into decades, until 2000 when they have data for five-year periods. Therefore, the three time periods analyzed are 1990 to 1999, 2000 to 2004 and 2005 to 2009. The first set of maps below, **Figures 5**, **6** and **7**, provide an opportunity for side-by-side comparison of census and municipal data. The maps on the left depict the number of units built according to ACS data while those on the right show the number of units indicated by the building permit data for each date range.

Figure 5 New Housing Units Based on U.S. Census and Austin Building Permit Data 1990 to 1999

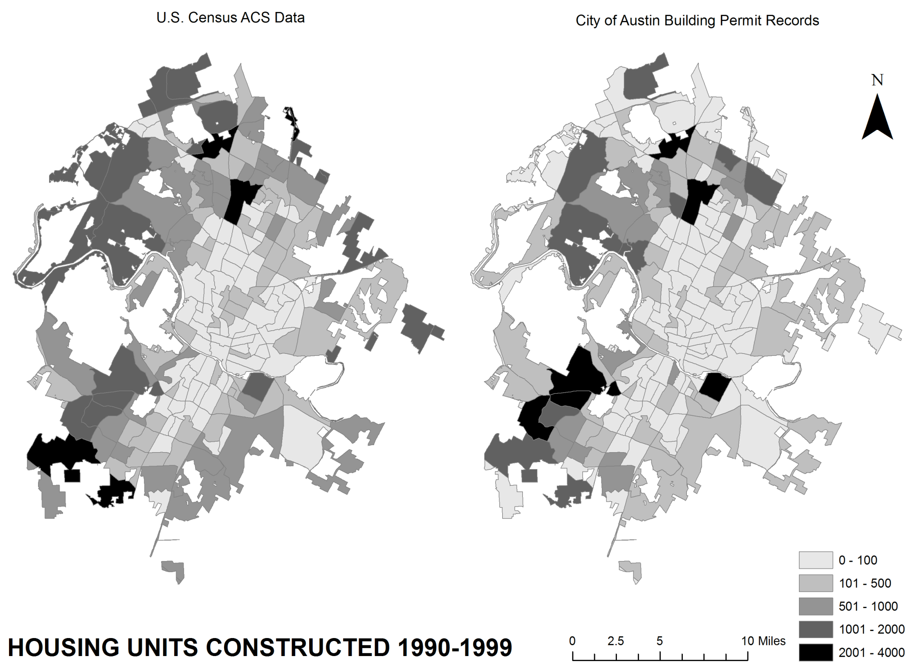


Figure 6 New Housing Units Based on U.S. Census and Austin Building Permit Data 2000 to 2004

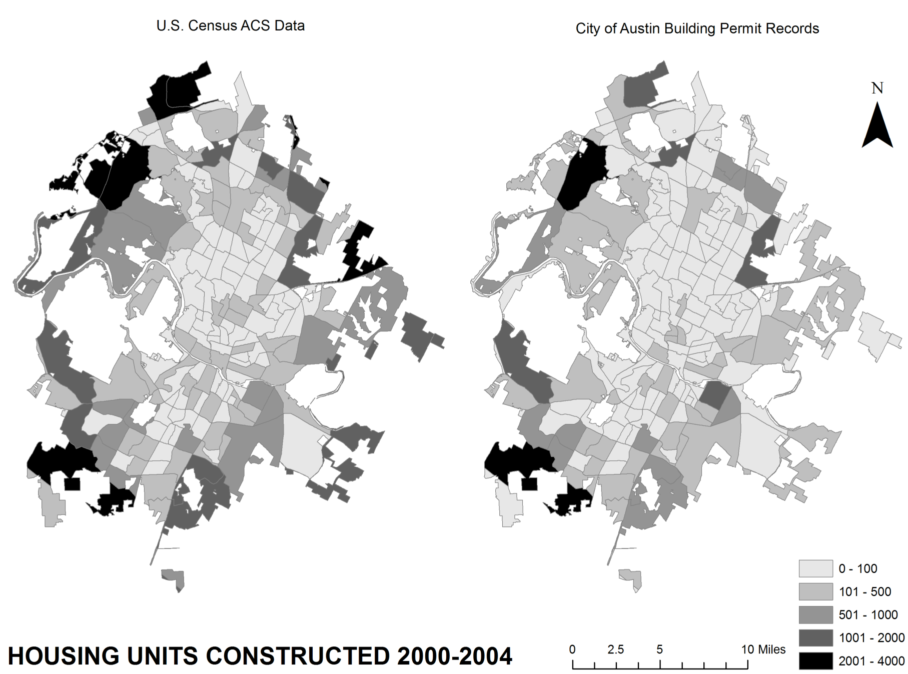
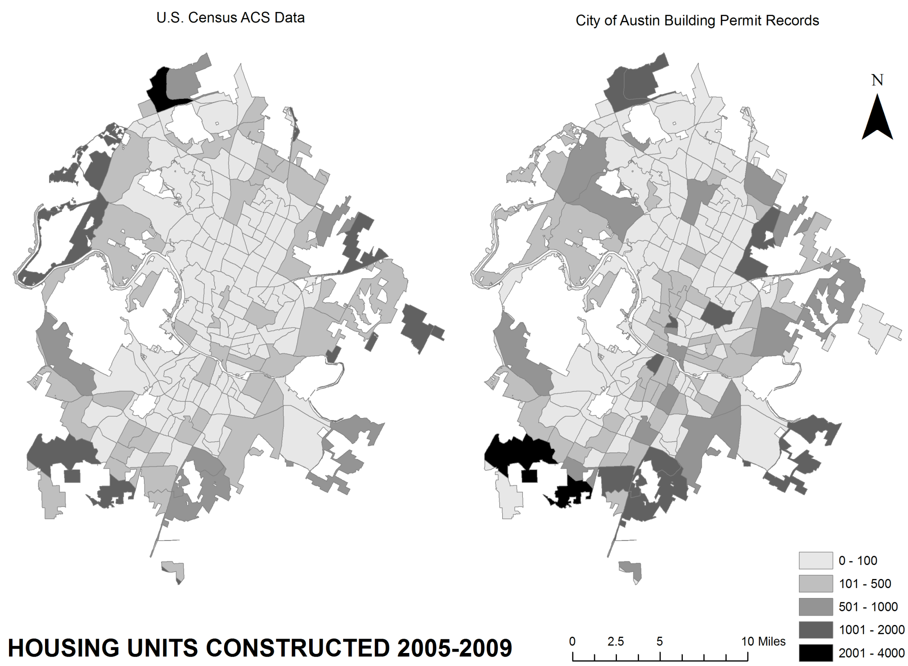


Figure 7 New Housing Units Based on U.S. Census and Austin Building Permit Data 2005 to 2009



In addition to the maps showing the actual unit counts, **Figures 8**, **9** and **10** aggregate the ACS and municipal information into one map to provide an alternative illustration of the data. The numbers in these maps indicate the absolute value of the difference between the ACS and municipal records for each time frame.

Figure 8 Absolute Value of Difference Between ACS and Austin's Permit Data 1990 to 1999

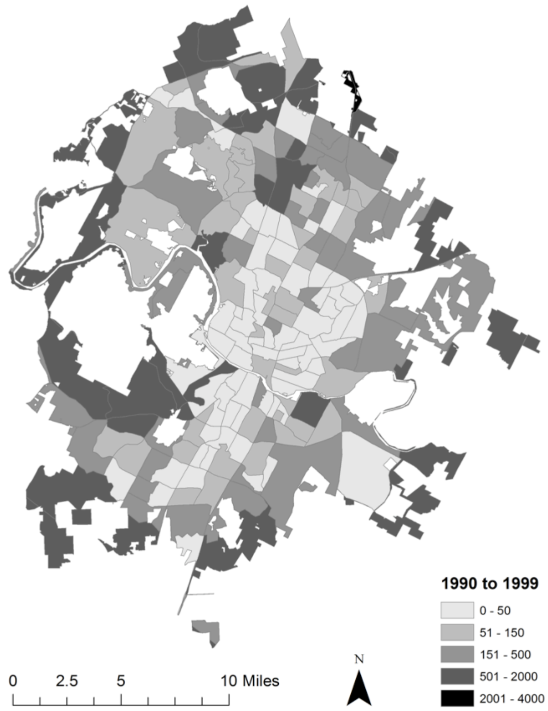


Figure 9 Absolute Value of Difference Between ACS and Austin's Permit Data 2000 to 2004

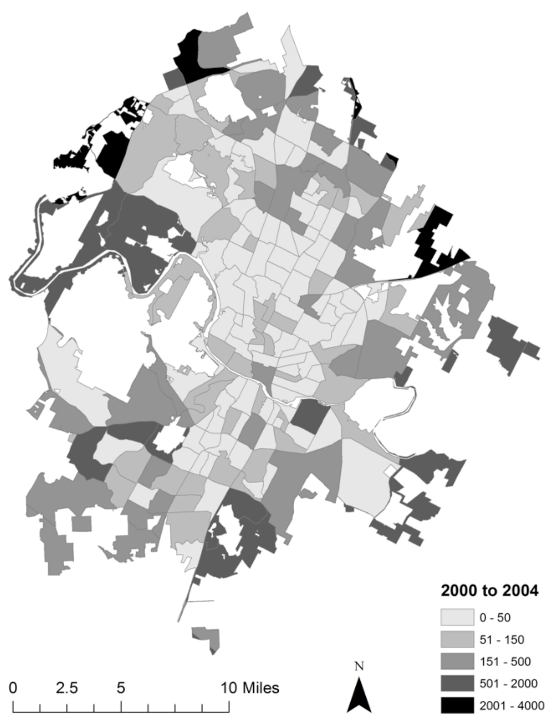
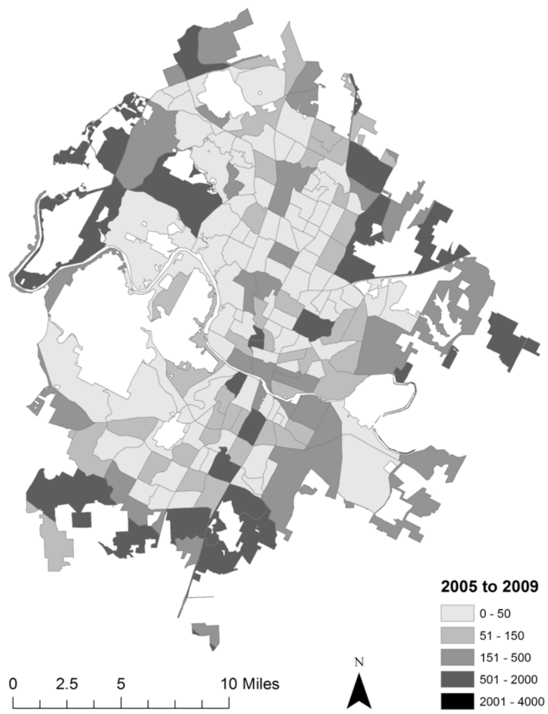


Figure 10 Absolute Value of Difference Between ACS and Austin's Permit Data 2005 to 2009



It is clear from these maps that the two datasets contain similar numbers in many cases, as several tracts show a difference of 50 housing units or less between datasets. However, there are tracts in Austin that show a difference of up to 4,000 housing units constructed. Many of these tracts are on the outer edges of the city boundaries and it is logical to assume that the Modifiable Areal Unit Problem (MAUP) described in Chapter 2 is an issue contributing to this difference. The MAUP basically describes an issue where incompatible geographic units make data comparisons and analysis difficult.

Austin is located primarily within Travis County, with small sections of the city located in adjacent Williamson and Hays counties. Of the 214 census tracts that divide these three counties, 189 of them intersect the Austin jurisdiction as identified in this study. Sixty-four of these tracts intersect but are not completely within Austin.

However, even considering only the tracts that are fully within Austin, and therefore not subject to the MAUP issue, some areas still show a difference between City and ACS data of over 1,000 housing units constructed. This may be attributable to the sampling error of the ACS data. One might also conjecture that as the ACS is dependent on knowledge or guesses of residents instead of official records, they may have inaccurately reported the year their residence was built. It would be unlikely, for example, for a renter to know the year when the structure that he or she lived in was built.

One additional factor to consider here, and in reviewing results throughout this study, is that record of a building permit does not always mean that a new housing unit is constructed. Though records with a permit status such as “withdrawn”, “void” or “inactive” were removed from the analysis dataset, there is no indicator in the data that tells a user if construction was completed, or even if it was started.

Figure 11, Figure 12, and Figure 13 show one further comparative picture of the two datasets. In addition to illustrating the difference between the ACS and City of Austin permit counts for new housing units these maps also indicate which dataset has the larger and smaller count for each tract. As we might expect, the ACS has a larger count of housing units and at the greater magnitude in the tracts on the edges of Austin. Again, the MAUP issue likely contributes to this discrepancy. The differences in the datasets are not consistent, however, meaning that one of the datasets does not always have a higher or lower count, or magnitude of count, than the other. This lack of consistency could indicate that ACS data may be difficult to normalize or control for error in an analysis of housing unit data. Another interesting note is that, in the first two time periods, the ACS data tends to be greater for the majority of census tracts, as seen in Figure 11 and Figure 12. However, the opposite is true for the years 2005 through 2009, shown in Figure 13. This illustrates further the inconsistency of ACS data on construction of housing units relative to local building permit records.

Figure 11 Difference Between ACS and Austin's Permit Data 1990 to 1999

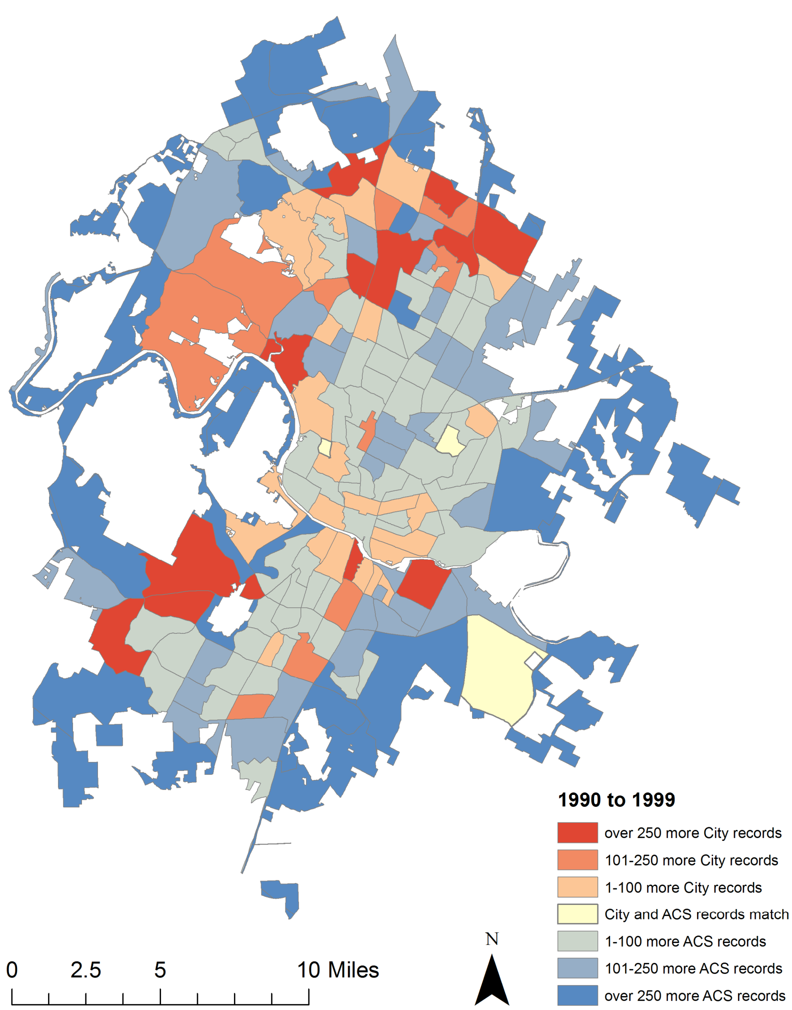


Figure 12 Difference Between ACS and Austin's Permit Data 2000 to 2004

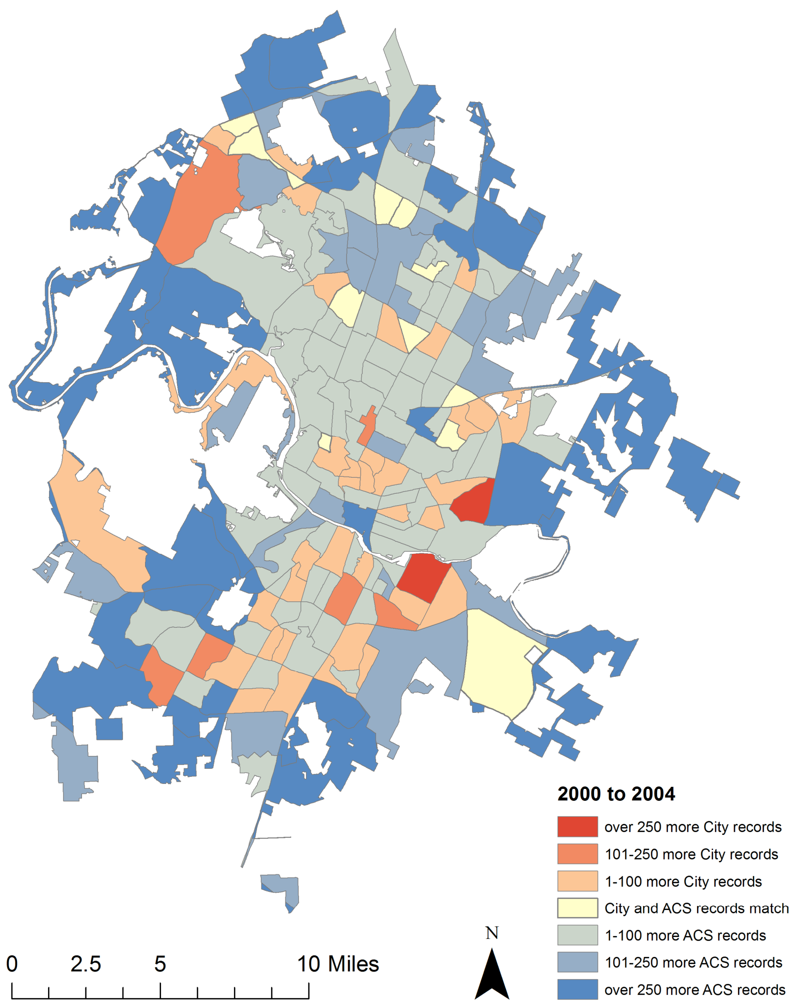
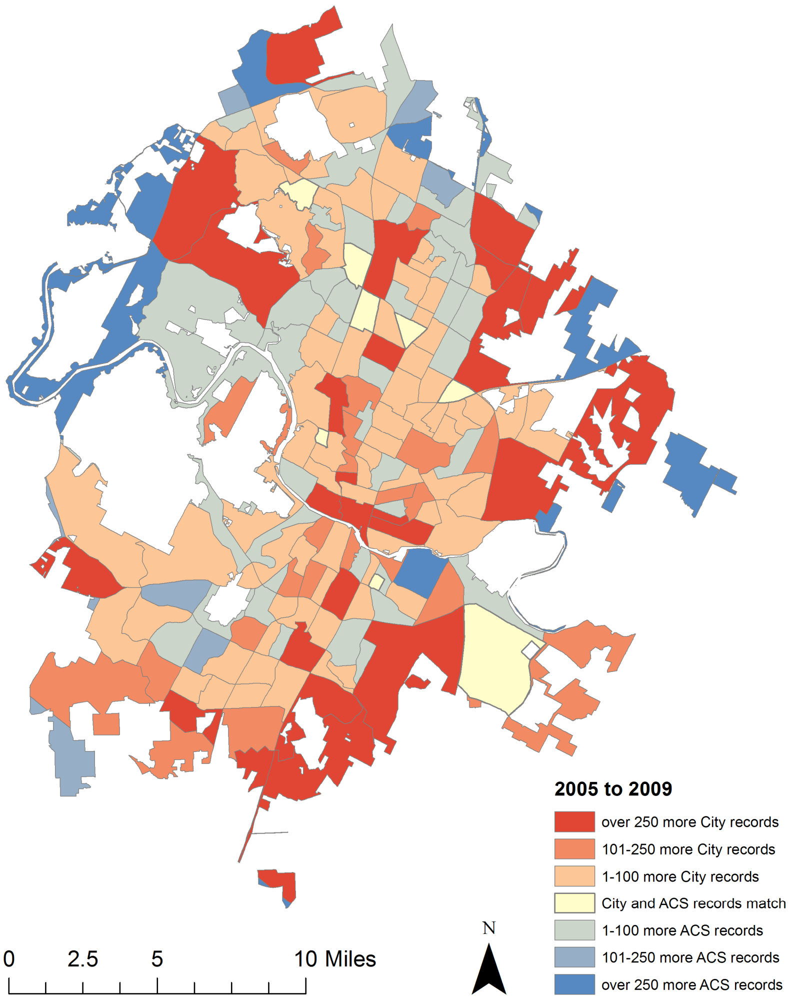
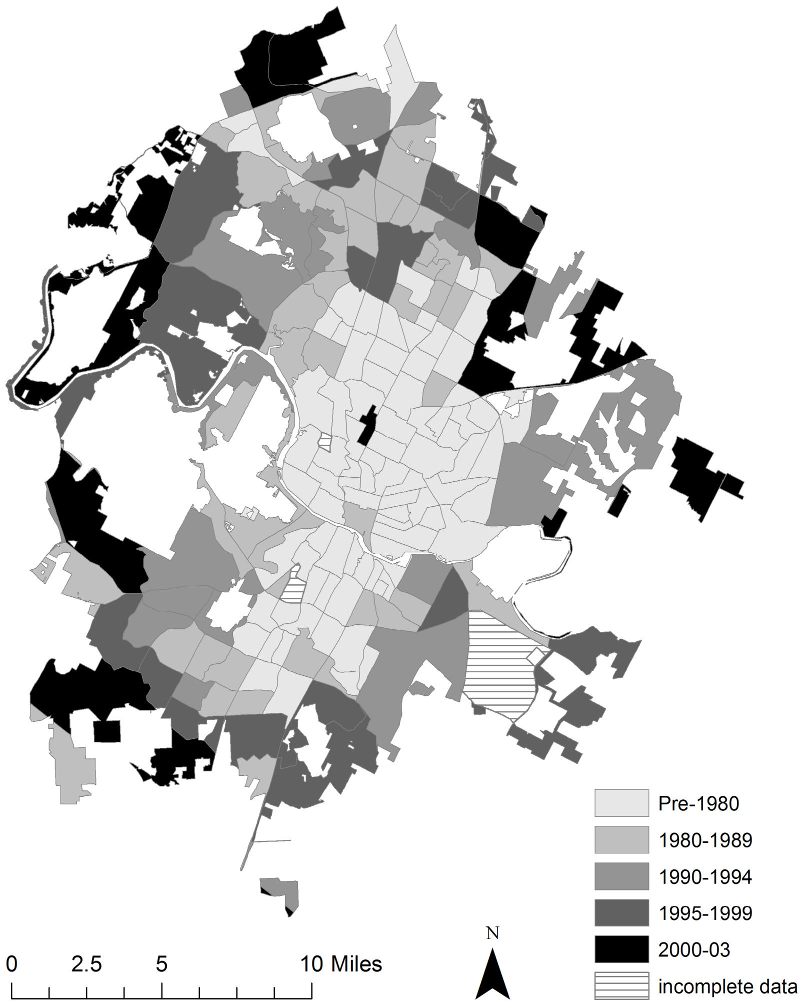


Figure 13 Difference Between ACS and Austin's Permit Data 2005 to 2009



Another piece of information collected by the ACS is the median year a structure was built. I was unable to directly compare this ACS data to Austin's records, as the permit database used in this study did not extend back beyond 1990. However mapping the median year of construction, as seen in Figure 14, does provide a useful summary of the age of housing stock and building trends in Austin. We can see for example that Central Austin has a relatively older housing stock and more recent construction has been concentrated on the edges of the city.

Figure 14 ACS Median Year Built Data for New Housing Units



6.1.4 Comparative Analysis Summary

In comparing census information to local government permit records, it was clear that using census data is problematic from several perspectives. This is true for each of the census products analyzed, including the Censtats building permit database, the decennial census and the ACS. Census data comes from surveys and estimates, which introduces sampling and reporting error. Further the data cannot be reliably allocated to city boundaries due to the static nature of census geographies. Where census boundaries don't conflict with city borders, the area and population covered by a census unit still do not allow for detailed review of neighborhood characteristics and trends. Additionally, the data is not continuous enough to effectively show change over time across the city. City building permit records provide benefits to an analysis of land development that census data cannot.

6.2 Case Studies

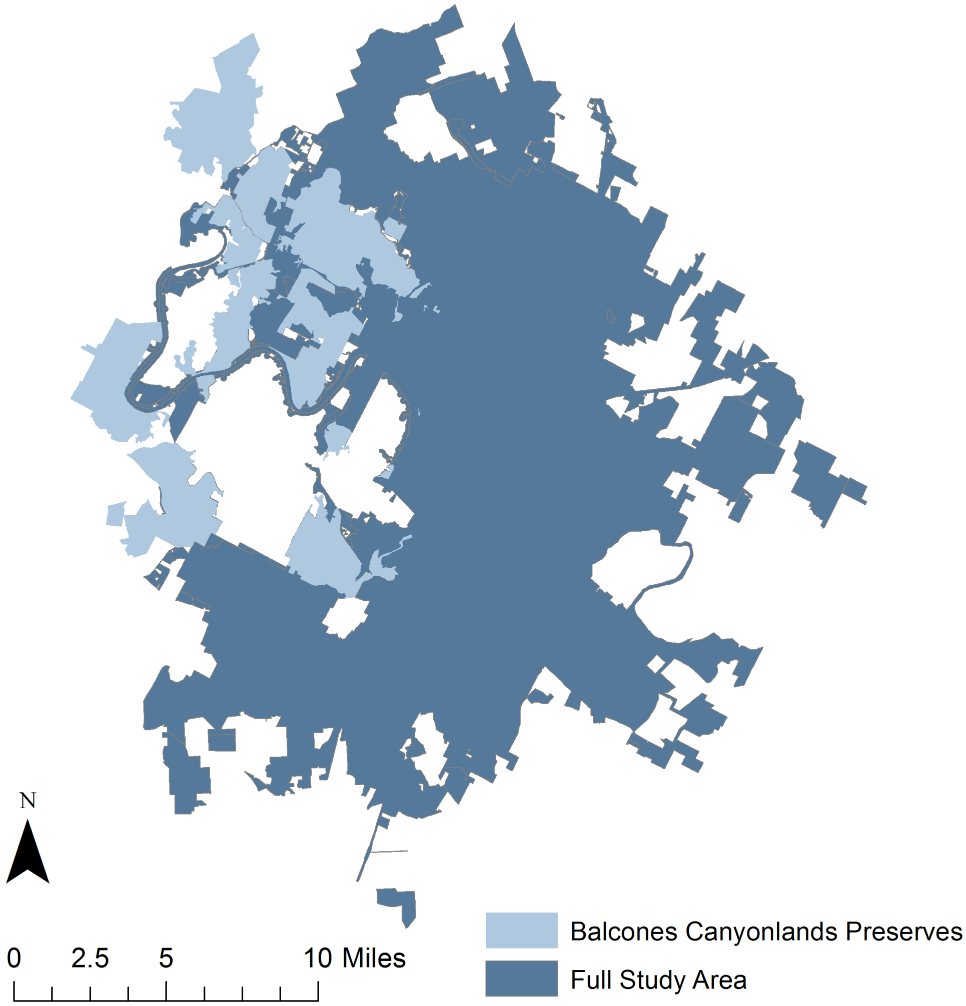
As part of my study, I chose three development-related initiatives and trends present in Austin. For each, I used the city's permit records and GIS to perform a spatial analysis in order to illustrate potential uses for the research approach. I chose to perform raster analyses as these best fit the data I had and the objectives for which I was aiming. The permit records that I worked with comprised a vector dataset. When mapped the records appeared as individual points, each point storing the characteristic data associated with each permit. A raster approach is a useful type of analysis for this data because a continuous surface can be created through this analysis indicating change and differences across a large area.

The three case studies that I decided on were a conservation project in the Balcones Canyonlands Preserve, Austin's Smart Growth Initiative aimed at assessing and controlling developmental growth, and gentrification in the city. In the course of my study I looked closely at four primary factors: the number of building permits, the size of the structures for which these permits were issued, the number of housing units and the recorded valuation of these projects.

6.2.1 Balcones Canyonlands Preserve

The conservation areas of the Balcones Cayonlands are located in the northwest of Austin, as illustrated in Figure 15. For this case study I focused on my primary dataset of new residential building permits and performed two types of analysis to show the relationship of housing development to conservation lands. Raster density surfaces were used to create a series of maps depicting the permit data in Austin. Following that, I used buffer and spatial join tools to obtain more information about residential permits issued in proximity to the preserve areas.

Figure 15 Map of Austin Study Area and BCP



6.2.1.1 Raster Density Surfaces

In creating density surfaces, I chose to focus on the number of permits and square footage data and created a series of maps for periods of time related to the Balcones conservation efforts. I broke down the data I had into three-year increments, starting in 1990 and going through 2007. As the conservation project began in 1996, I made sure that this was a starting year for one of the time periods in order to capture the initial years of the initiative as well as being able to see development patterns before it was begun for comparison.

After exploring different specifications for the raster density surfaces, I determined that a kernel density[2] analysis with area units of square miles worked best for my demonstrations. Additionally, I kept the search radius constant at 10,520 feet, or two miles, and set the output cell size as one hundred feet.

Figure 16 through Figure 21 are a series of maps demonstrating the shifts in the number of new residential building permits issued from 1990 through 2007. We can see that a high density of permits is issued in the southwest of Austin throughout the analysis period. The density of permits in the northwest portion of the city does slowly diminish however, and a higher concentration of permits is apparent on the eastern side of the city in more recent years.

[2] "The Kernel Density tool calculates the density of features in a neighborhood around those features. It can be calculated for both point and line features" (ESRI 2011).

Figure 16 Building Permit Density per Square Mile 1990 to 1992

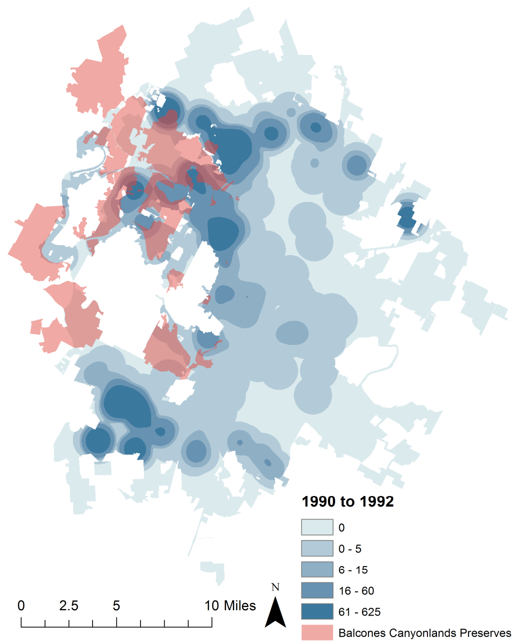


Figure 17 Building Permit Density per Square Mile 1993 to 1995

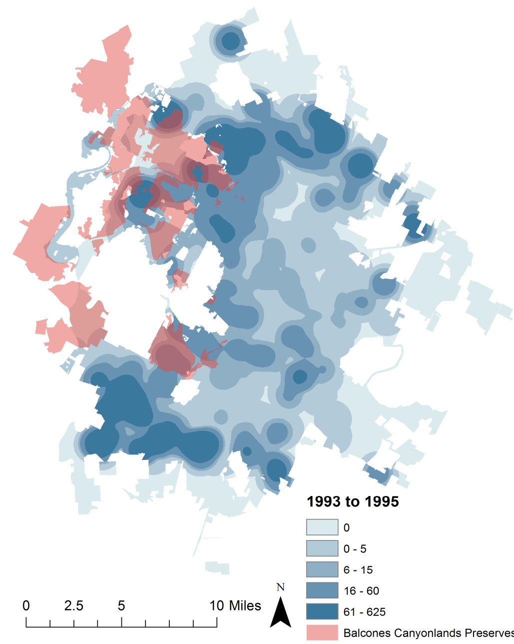


Figure 18 Building Permit Density per Square Mile 1996 to 1998

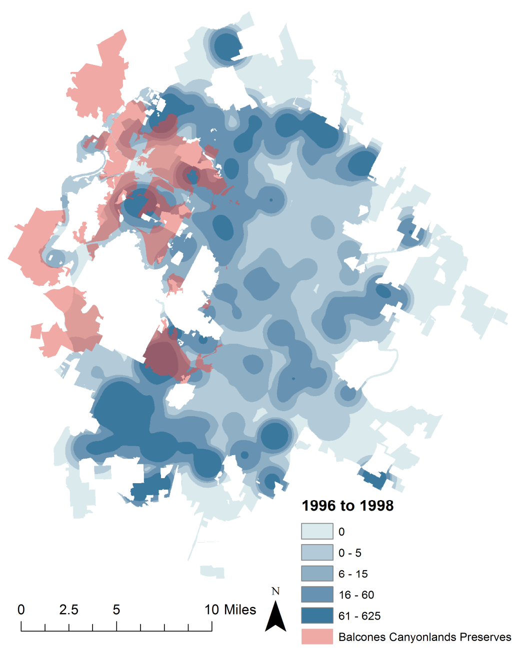


Figure 19 Building Permit Density per Square Mile 1999 to 2001

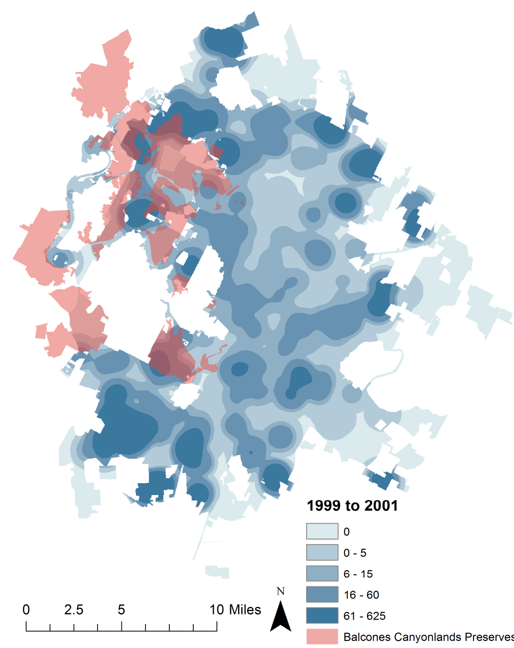


Figure 20 Building Permit Density per Square Mile 2002 to 2004

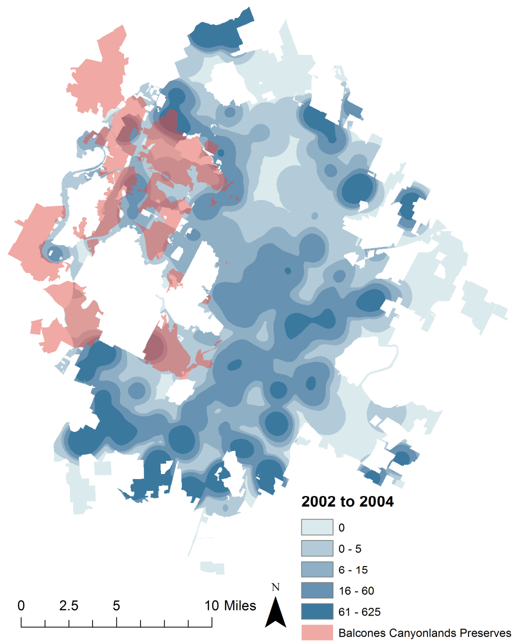
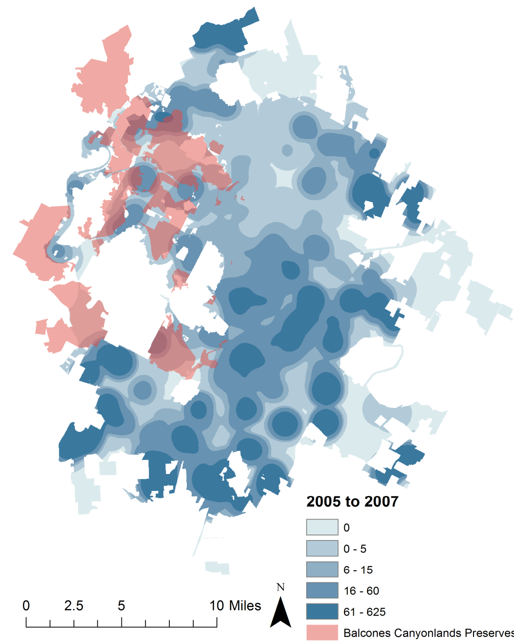


Figure 21 Building Permit Density per Square Mile 2005 to 2007



Figures 22 through **27** map the square footage of residential construction permitted using the same increments of time as the previous series of maps. In general, the trends are very similar, where there were more permits, there was more building area constructed. Looking at a specific characteristic of the permits provides another way to present the data. Additionally, by comparing these two series of maps, we can identify areas where there are differences to focus on and hypothesize further. For instance, an area where there is a high concentration of permits issued but low square footage could imply smaller homes being constructed. To support this hypothesis, we might map additional permit characteristics, such as number of units and construction value.

Figure 22 Area (sf) Density of Building Permits 1990 to 1992

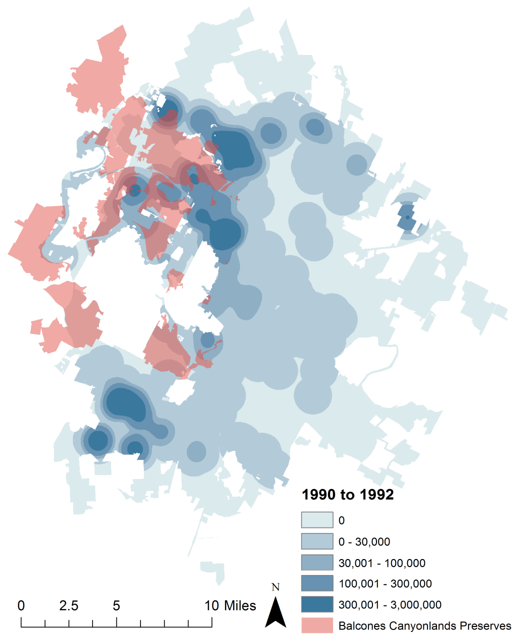


Figure 23 Area (sf) Density of Building Permits 1993 to 1995

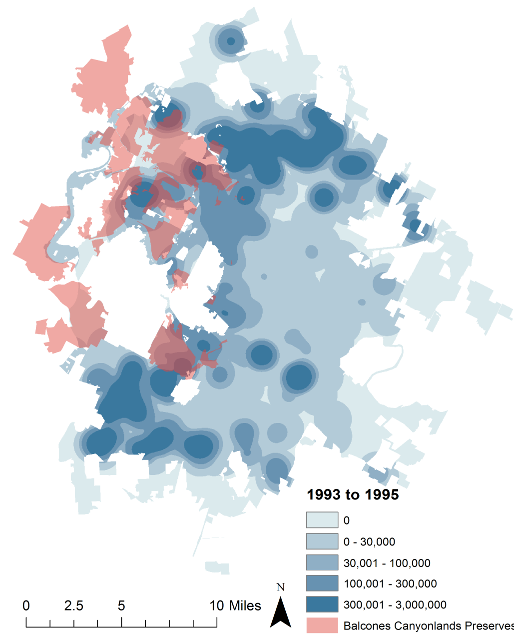


Figure 24 Area (sf) Density of Building Permits 1996 to 1998

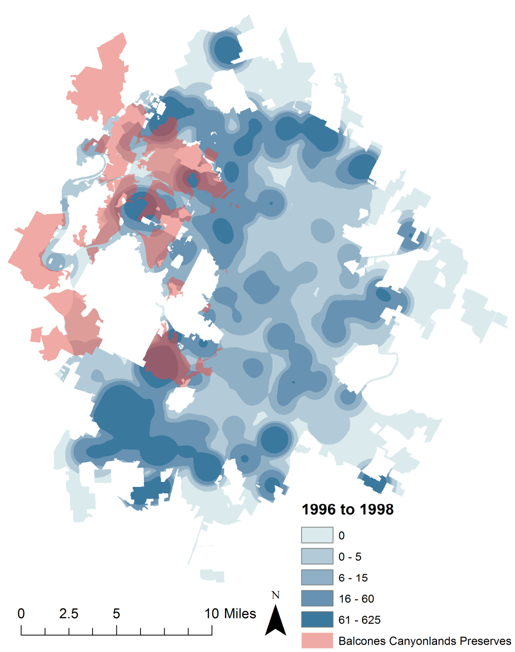


Figure 25 Area (sf) Density of Building Permits 1999 to 2001

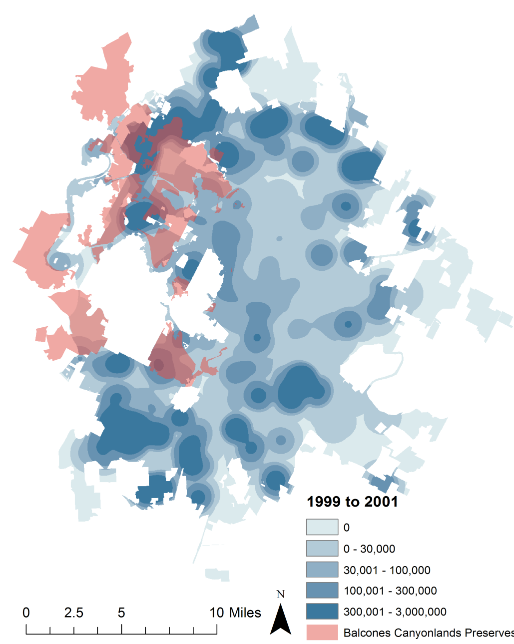


Figure 26 Area (sf) Density of Building Permits 2002 to 2004

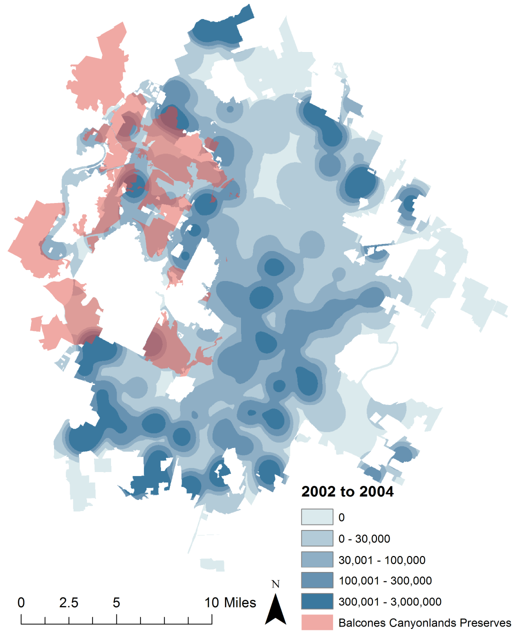
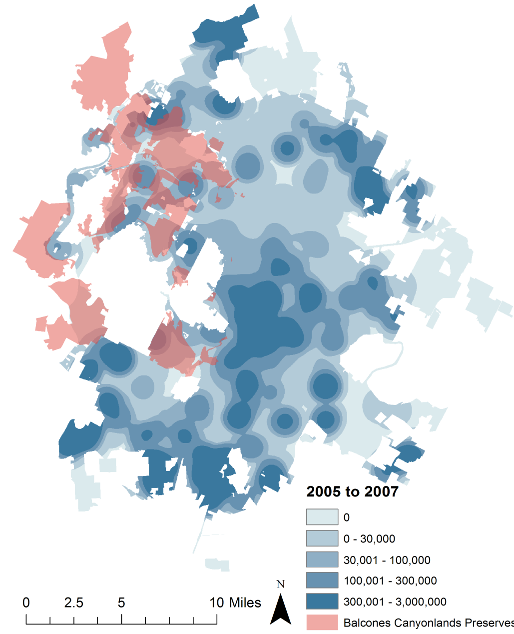


Figure 27 Area (sf) Density of Building Permits 2005 to 2007

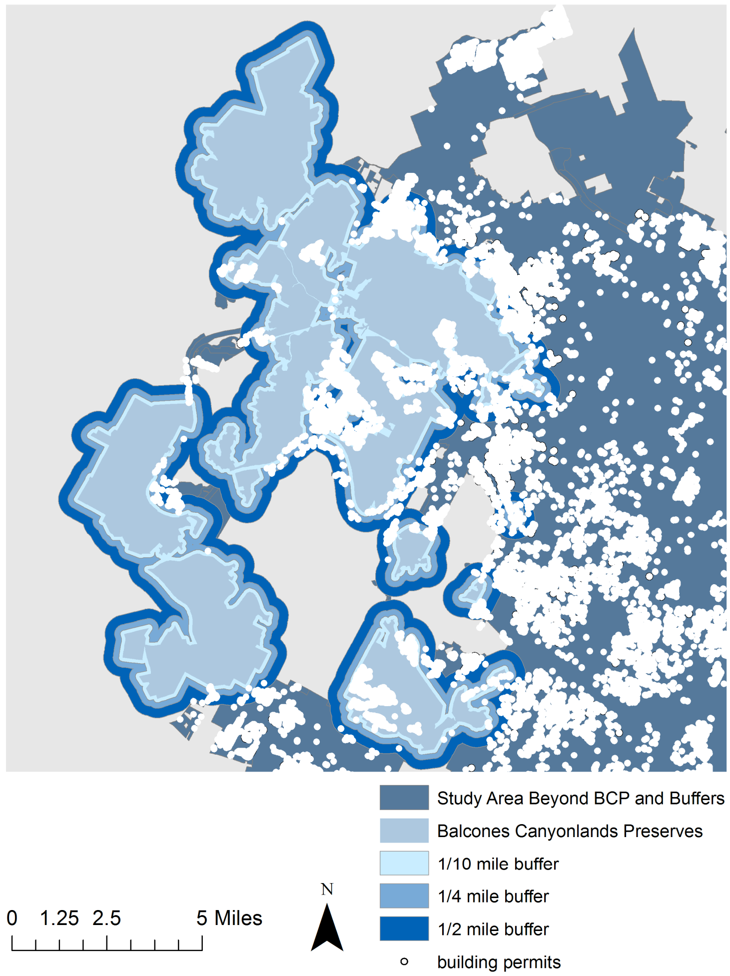


From these visualizations, we can see that the density of development does shift over time, becoming more concentrated on the eastern portion of the city, particularly the southeastern area. The density of development specifically around the Balcones Conservation lands is less in the most recent period analyzed from 2005 to 2007 than in the time periods prior to the beginning of the preservation initiative in 1996. However, shortly after the start of the project, the concentration of residential development near some of the BCP lands stayed steady or increased, as illustrated in **Figures 17** and **24** that show data for the 1999 to 2001 time period. One possible explanation for this is that people wanted to build there because the nearby preserves increased property values or provided assurance against overdevelopment in the area.

6.2.1.2 Multi-Ring Buffers

I also performed a buffer analysis where I created multiple rings of buffers around the conservation lands at various distances including one-tenth, one-quarter and one-half mile from the edges of the BCP polygons. I then aggregated the permit data to the buffers to obtain summary statistics of development within the designated distances. This data is visualized in the graphs of **Figures 35**, **36** and **37** discussed later in this chapter. A full view map of the buffers themselves, as shown in Figure 28, does not provide a great deal of information. However, taking a closer look at some of the buffer areas overlaid with permit point data over time can provide a more interesting and informative series of maps, as illustrated in **Figures 28** through **34**.

Figure 28 BCP Lands, Buffers and Building Permits



By creating buffers I was able to make maps showing the locations and concentrations of building permits that were issued within specified distances of the preserve lands. The maps in Figure 29 through Figure 34 below show the accumulation of permits issued in one area of northwestern Austin bordering the Balcones preserve lands. The accumulation of permits before the conservation initiative, when it initially began and to the present is illustrated. The red dots show the permits that were issued within the time period specified on the map, while the white dots represent the permits issued from the beginning of the analysis period, 1990, up until the current period noted. This small-area view of the buffer analysis can be performed on any area of the conservation boundaries.

Figure 29 Building Permits 1990 to 1992

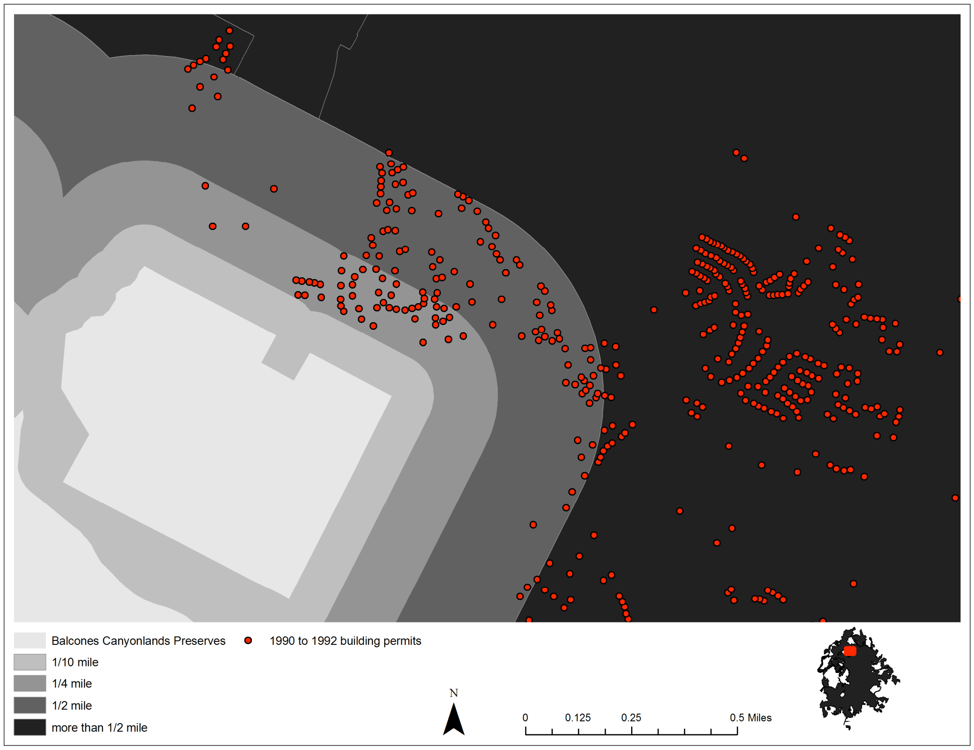


Figure 30 Building Permits 1993 to 1995

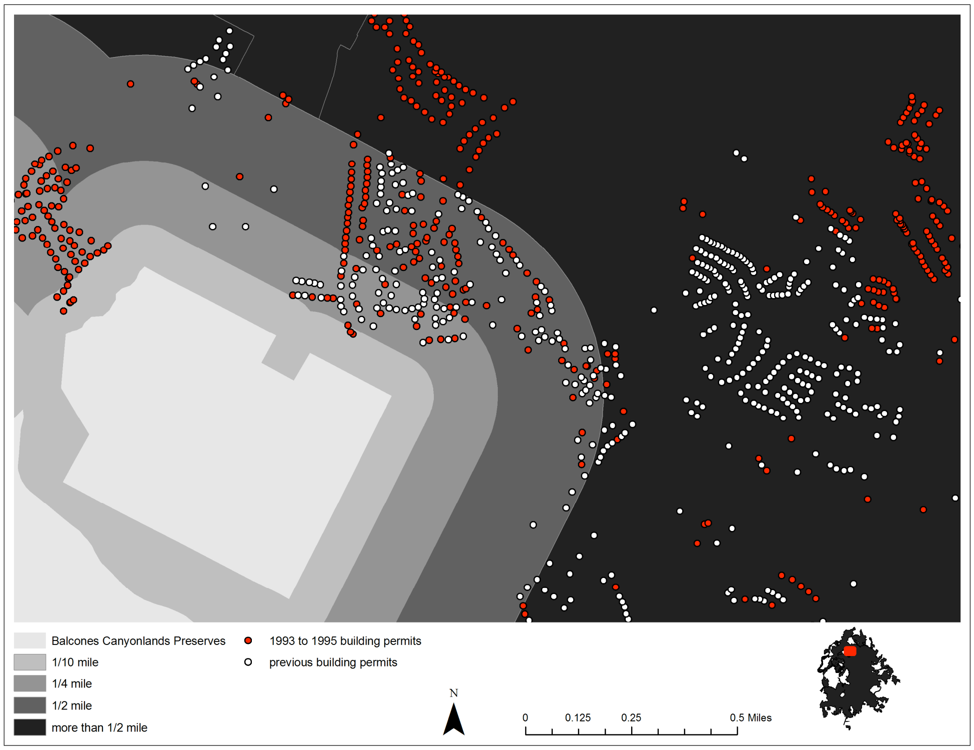


Figure 31 Building Permits 1996 to 1998

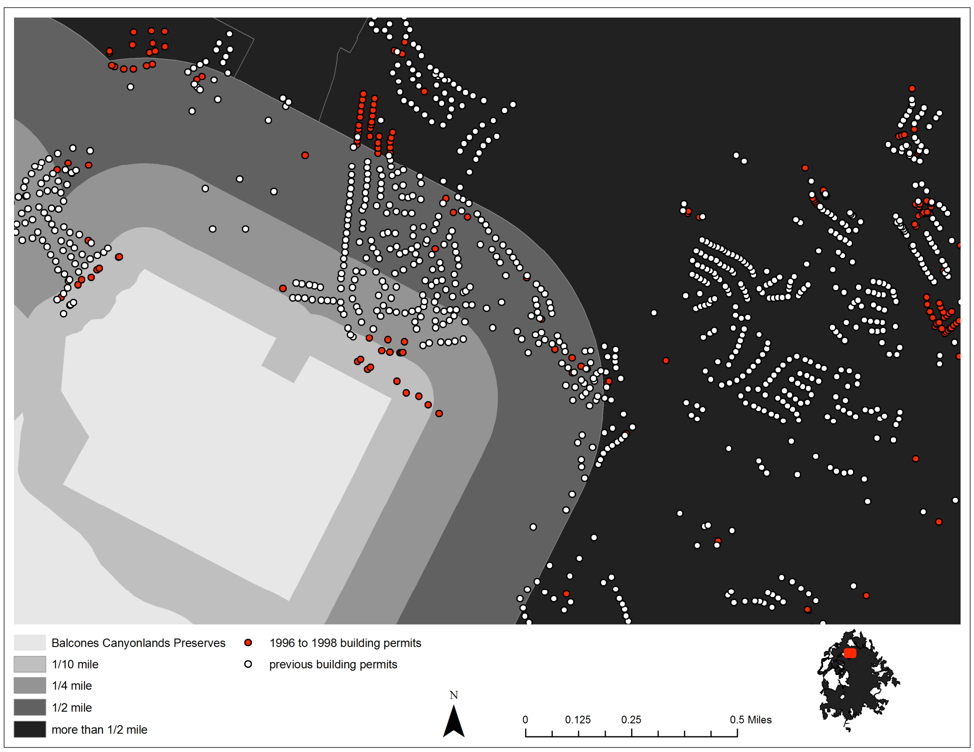


Figure 32 Building Permits 1999 to 2001

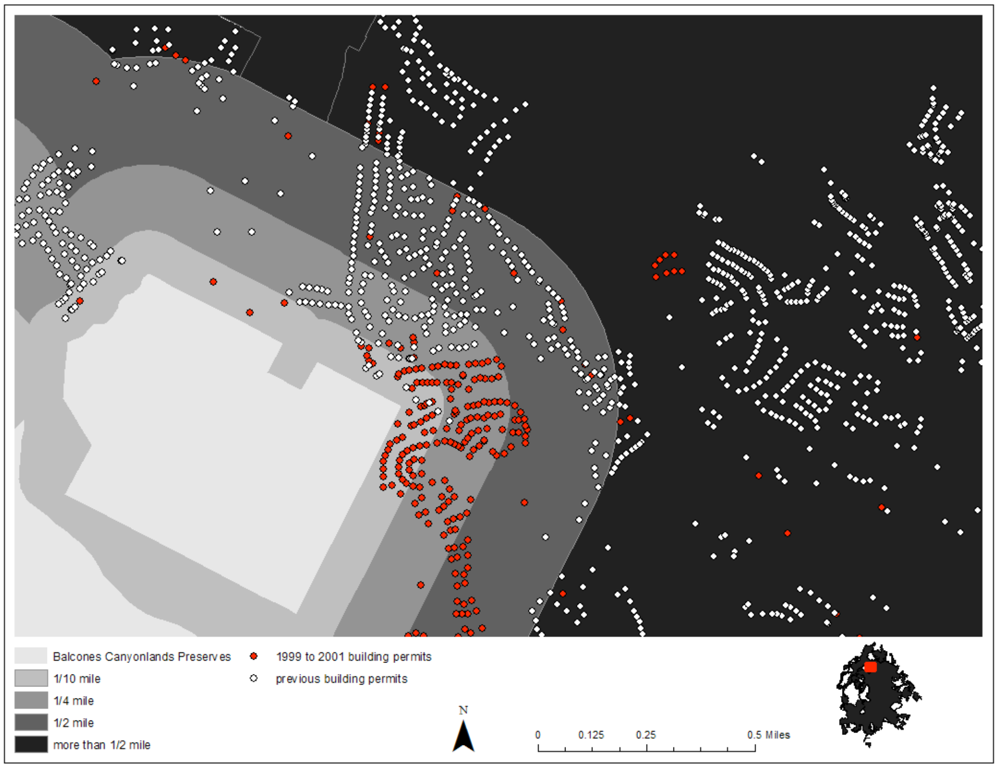


Figure 33 Building Permits 2002 to 2004

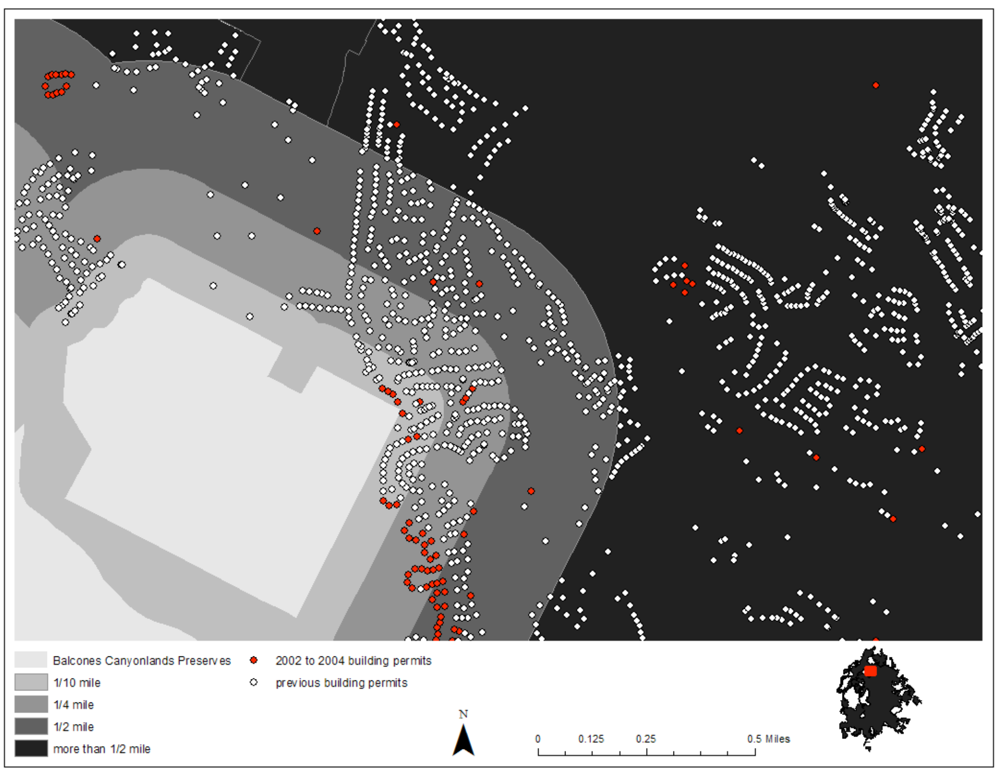
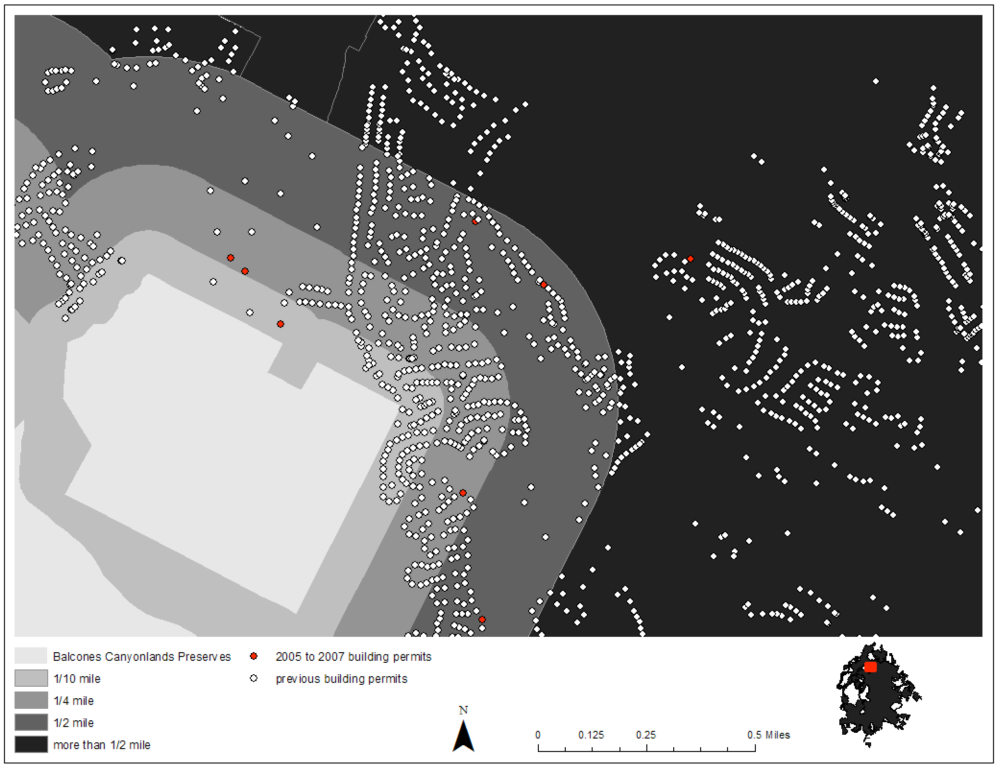


Figure 34 Building Permits 2005 to 2007



In addition to visuals such as the previous maps, performing a spatial join of permit records to the buffers creates summary information regarding permits issued in close proximity to the conservation lands. The graphs below in **Figures 35, 36** and **37** summarize the number of permits issued, the total count of housing units (as single permits are issued for multi-unit structures) and total square footage recorded of new construction within one-tenth, one-quarter and one-half mile of the conservation property boundaries over time.

Figure 35 New Residential Permits Issued Near the BCP

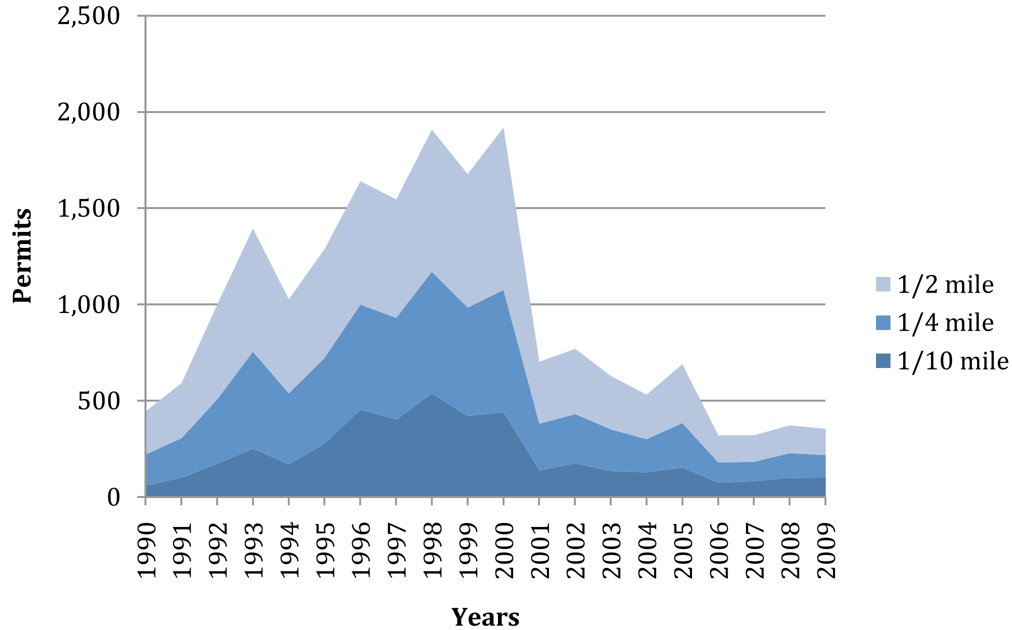


Figure 36 Housing Units Permitted Near the BCP

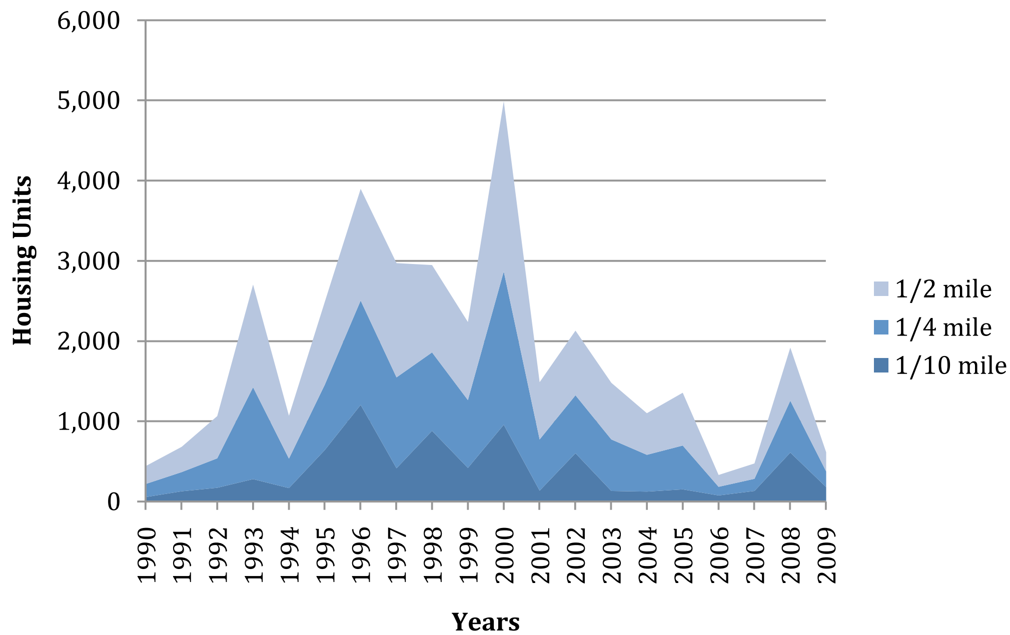
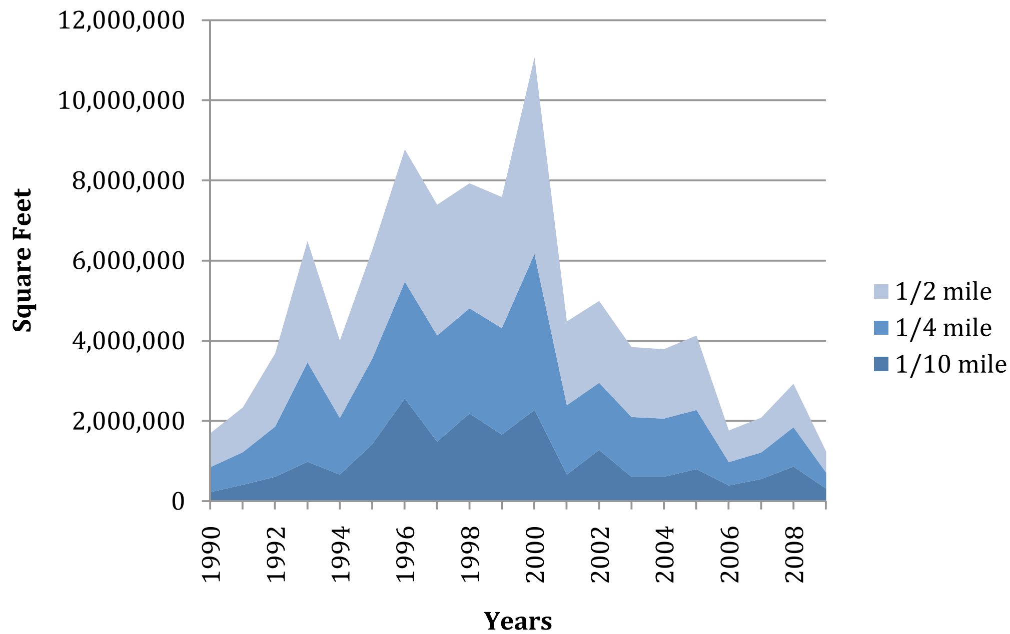


Figure 37 Square Feet of Residential Development Permitted Near the BCP



This type of analysis can help planners and policy-makers to determine where residential construction is being permitted in relation to the conservation lands and allow them to theorize whether establishing the preserve affected development patterns beyond preventing individuals from constructing within the actual preserve areas. My analysis shows an overall general trend of increasing numbers of permits issued within a half-mile of the BCP lands from 1990 to 2000. We see a sharp drop in permits from 2000 to 2001, followed by a general downward trend. From this, we can see that development has generally slowed in near the BCP in the last decade from 2000 to 2009. Further, from this data analysis, more specific questions can be answered regarding whether more permits were granted for home construction within a tenth of a mile of the preserves before or after the project was initiated in 1996, and whether the size or value of residences permitted changed through the timeframe. By utilizing additional data available in the permit records, researchers can answer more questions such as: what the trends were in single versus multi-family permits issued in relation to conservation, or how many homes were renovated in the area in comparison to new homes that were built. By including other land uses from the building permit database (such as commercial and industrial), researchers would also be able to compare these types of development to residential development within the buffer areas.

6.2.2 Smart Growth Initiative

Austin's Smart Growth Initiative (SGI) which was in place from 1998 to 2007, is the second case study used to demonstrate possible applications of municipal data and GIS. Figure 38 shows a map of the study area in Austin and highlights the two Desired Development Zones (DDZs) designated under the SGI. The DDZs were areas where the city provided incentives for developers to build in order to encourage targeted growth. The raster calculator and spatial join tools were used in this case study.

Figure 38 Desired Development Zones

6.2.2.1 Visualizing change through time

In studying the SGI, we can look back to the density surface maps created for the BCP to view general trends. To make these maps more applicable to the SGI, I could repeat the analysis, breaking the data down into time periods more relevant to the SGI timeframe and adding the DDZ boundaries. In order to demonstrate another type of analysis though, I chose to use the raster calculator to review the differences in individual years related to the SGI and its associated DDZs.

For this assessment, I created density surfaces of individual years instead of groups of years. I then used the raster calculator to compare them.
The density surfaces below illustrate trends and concentration of permits issued in Austin. These can be analyzed relative to the DDZ boundaries to determine if the SGI is having the effected it intended by incentivizing specific areas for development. The map in Figure 39 shows the difference between permits issued in 2009 and 1990, the first and last years of the study timeframe. Figure 40 and Figure 41 illustrate years more directly related to the SGI. The year 1998 was when the initiative began and 2007 was when it ended. The Smart Growth Matrix associated with the SGI was ended in 2003 and therefore this year is also included in the spatial analysis for an additional perspective.

Figure 39 Difference in Density of Permits Issued in 1990 and 2009

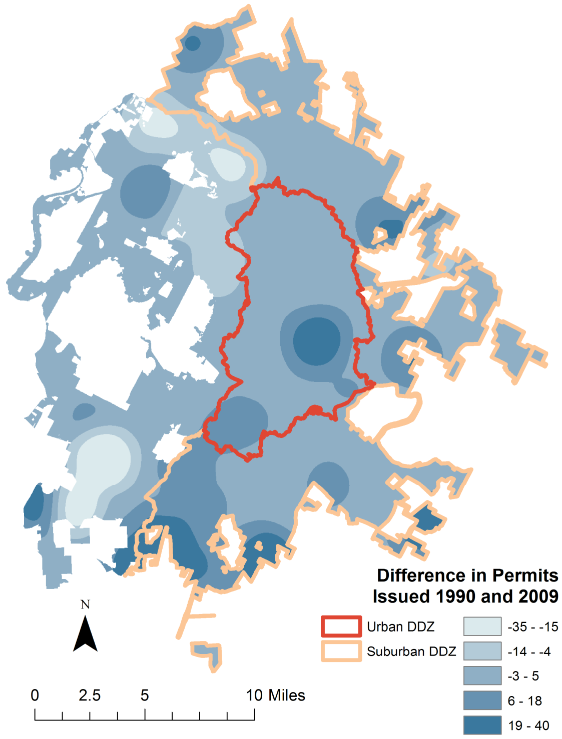


Figure 40 Difference in Density of Permits Issued in 1998 and 2003

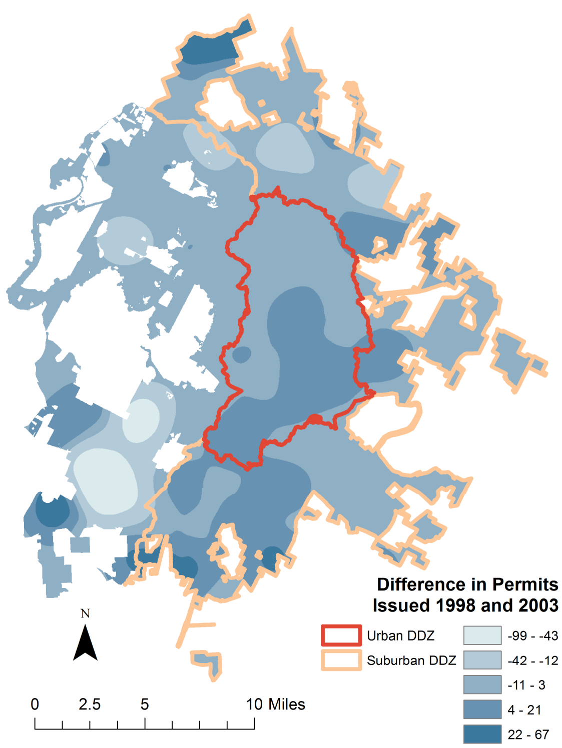
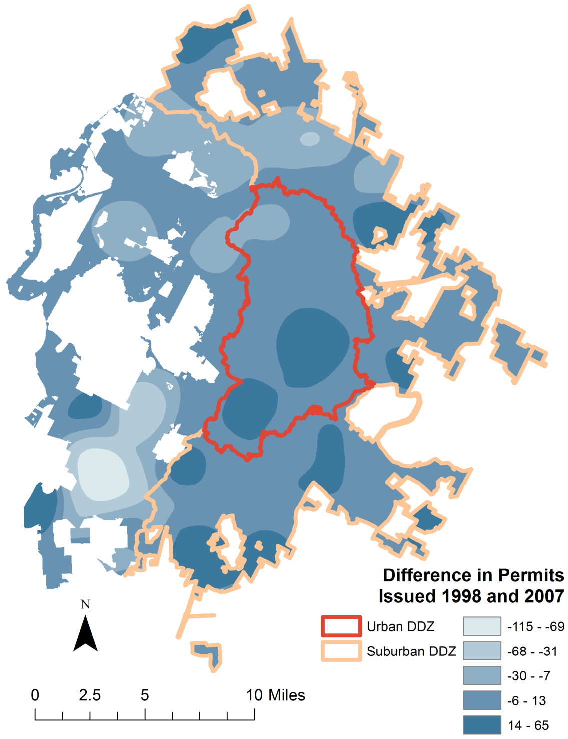


Figure 41 Difference in Density of Permits Issued in 1998 and 2007



In addition to subtracting the permit density surfaces for key years to create a picture of change relevant to the SGI, I also used the raster calculator tool to aggregate information for the years that the initiative was in effect as well as the years leading up to it from 1990 to 1997. The results of summing these density surfaces are illustrated in **Figures 42**, **43** and **44**. From these maps, we can see that the highest concentration of development is on the west side of the city overall. However during the SGI time period the densities of permits issued do increase on the eastern portion of the city, where the DDZs are located.

Figure 42 Density of Permits Issued 1990 to 1997

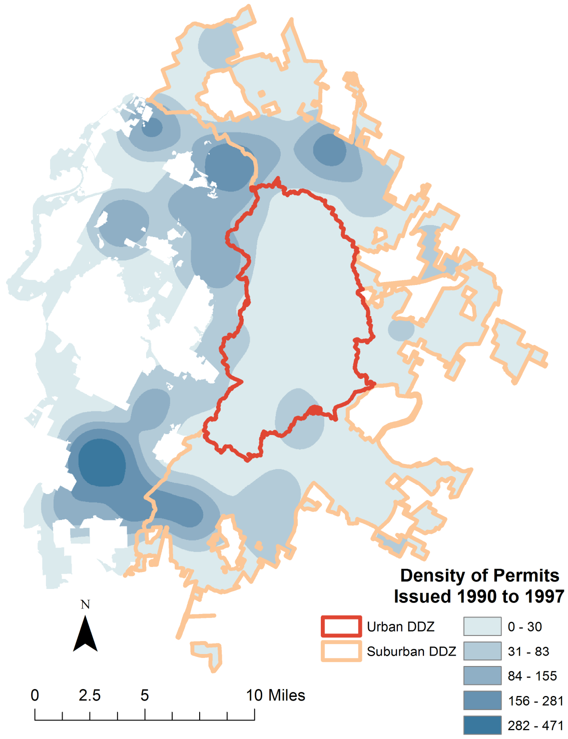


Figure 43 Density of Permits Issued 1998 to 2003

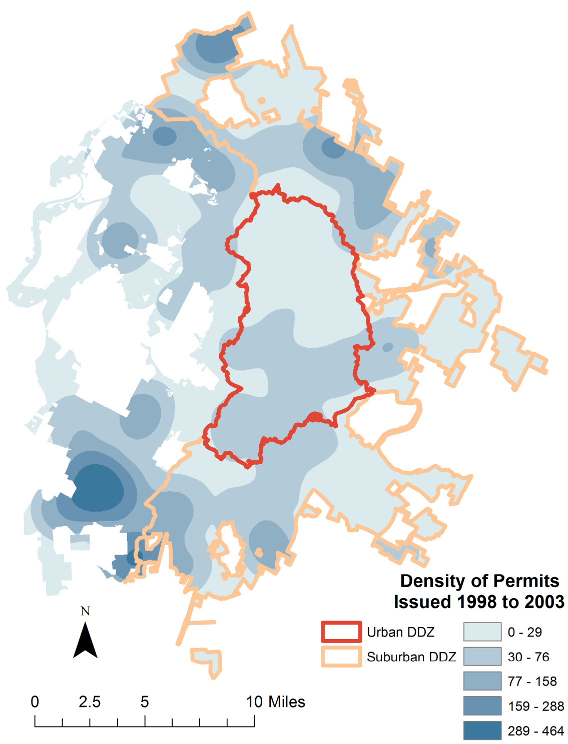
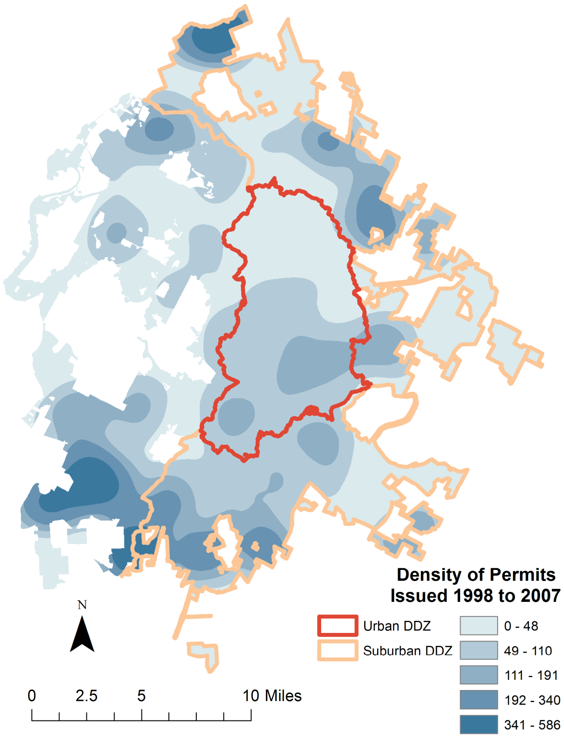


Figure 44 Density of Permits Issued 1998 to 2007



6.2.2.2 Spatial Join

For the SGI demonstration, I wanted to compare development within the DDZ to the rest of Austin and the city as a whole. In order to do this I performed a spatial join of permits directly to the DDZ polygon. By doing a spatial join of Austin's building permit data to the Desired Development Zone designated by the SGI, I was able to compare the characteristics of permits issued within the DDZ to all permits issued in Austin for the period from 1990 through 2009. The graph in Figure 45 below shows the trends in the number of residential housing units permitted within the DDZ. The number of units permitted within the DDZ has increased overall over time. There was a downward trend from 1996 to 1998, but the number of units permitted began increasing again in 1998, the year the SGI was initiated. Figure 46 summarizes the characteristics of residential building permits issued within the DDZ as a percentage of those issued overall in Austin from 1990 through 2009. The portions of all three permit factors within the DDZ areas charted below – the number of housing units, square footage and construction valuation – all increased over the past two decades. They all hit a peak of between 80 and 90 percent in 2007.

Figure 45 Housing Units Permitted in Austin and DDZ

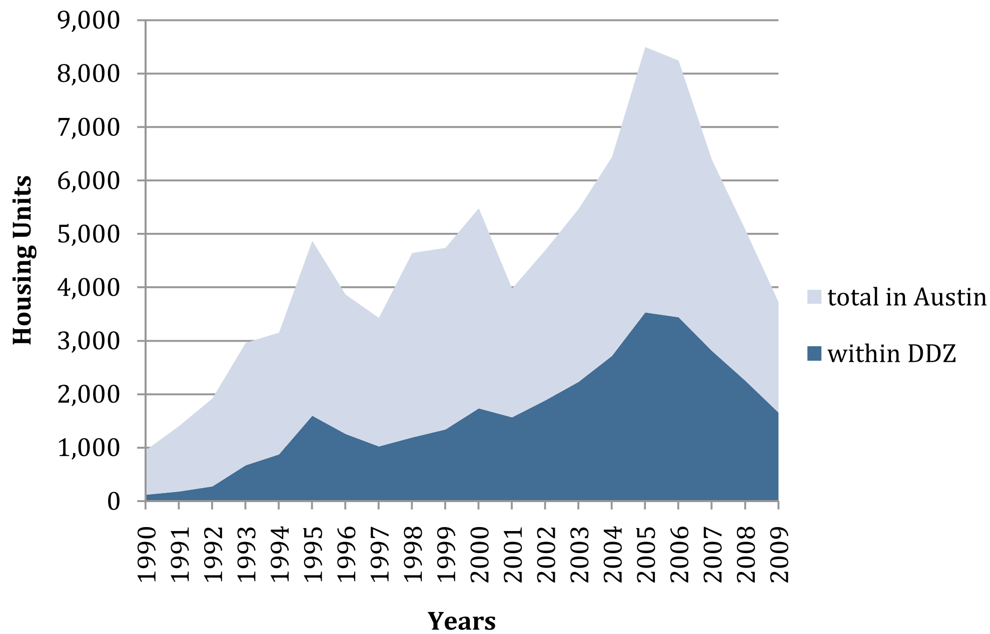
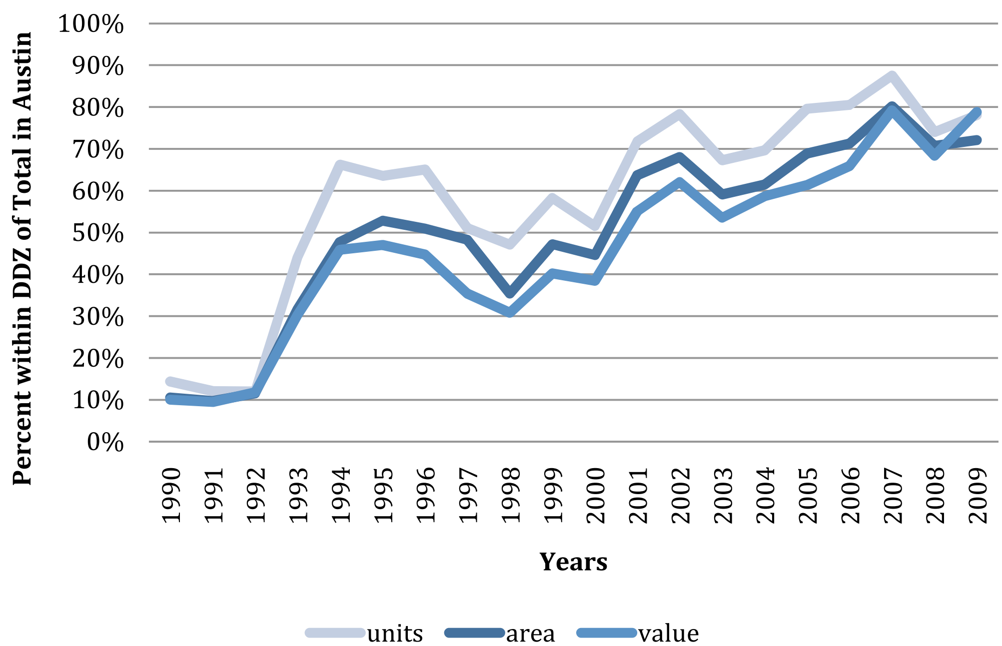


Figure 46 Characteristics of Permits Issued within DDZ over Total

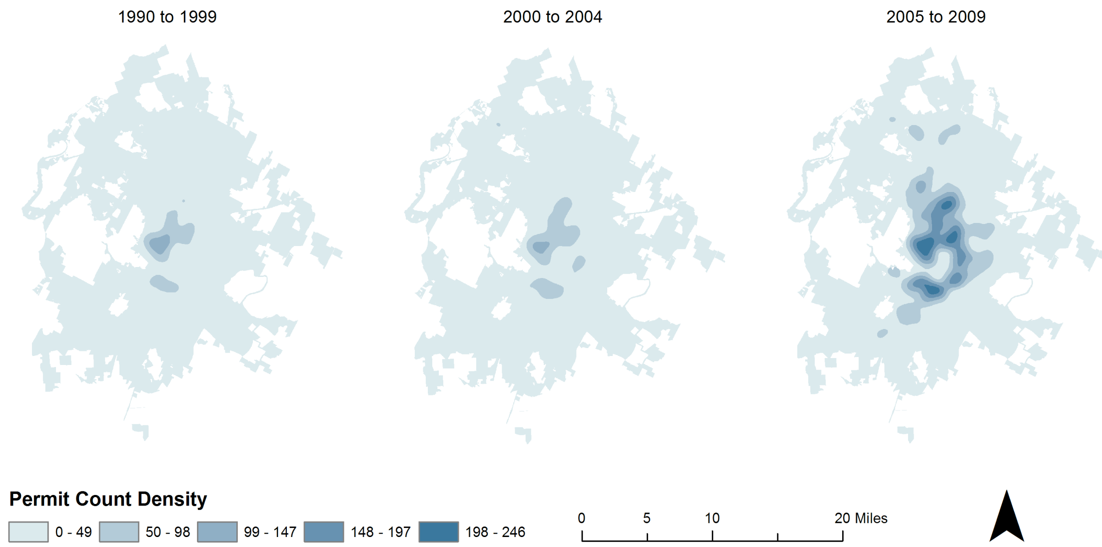


The Smart Growth Initiative included incentives for other types of construction in addition to residential. Studying commercial building permit trends would be another way to explore the SGI through a spatial analysis.

6.2.3 Gentrification

For the final case study, I looked at gentrification in Austin. To do this, I did not use the primary dataset of new residential building permits. Instead, I went back to the larger dataset containing all types of permits and extracted those classified as renovations, since housing upgrades are more frequently associated with gentrification than new construction. I broke this case study analysis down into three time periods: 1995 to 1999, 2000 to 2004 and 2005 to 2009. In the initial phase of my analysis, I created raster density surfaces based on the permit counts, as I did for the BCP and SGI case studies. The results of this are illustrated in Figure 47. This step made clear that a majority of the renovation work in Austin was occurring towards the center of the city, to the west and southwest of downtown. Based on this I focused into this central area more closely for the rest of the spatial analysis.

Figure 47 Densities of renovation permits in Austin over time



Figures 48, **49** and **50** are simple point maps identifying the locations of renovation permits in Austin's urban core for the specified time periods. The white dots are address-located points, providing a highly accurate picture of where renovation work was permitted.

Figure 48 Renovation Permits 1995 to 1999

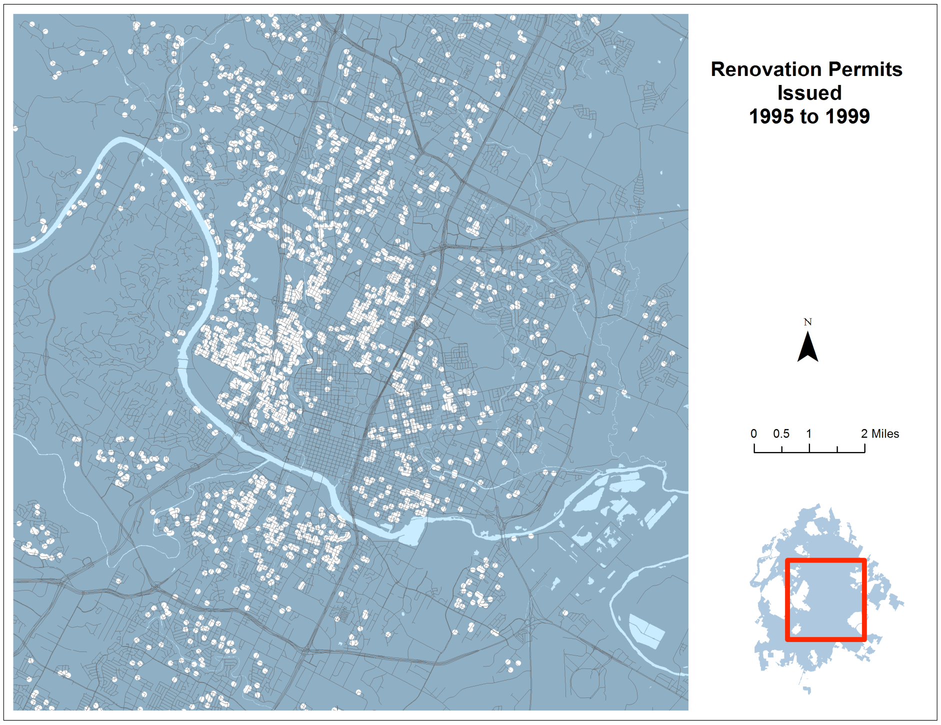


Figure 49 Renovation Permits 2000 to 2004

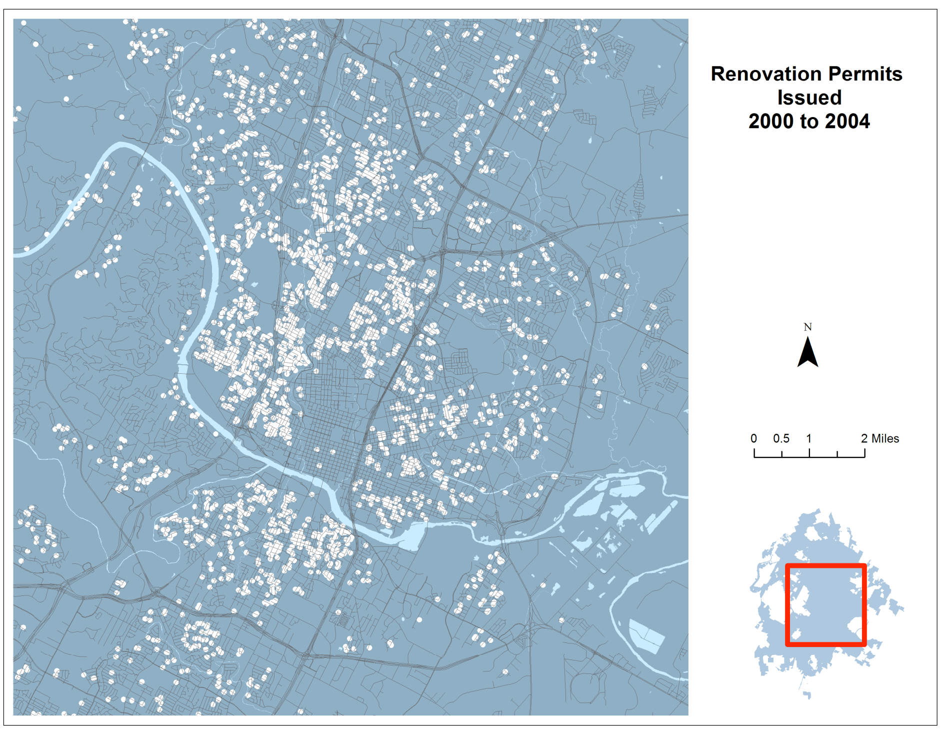
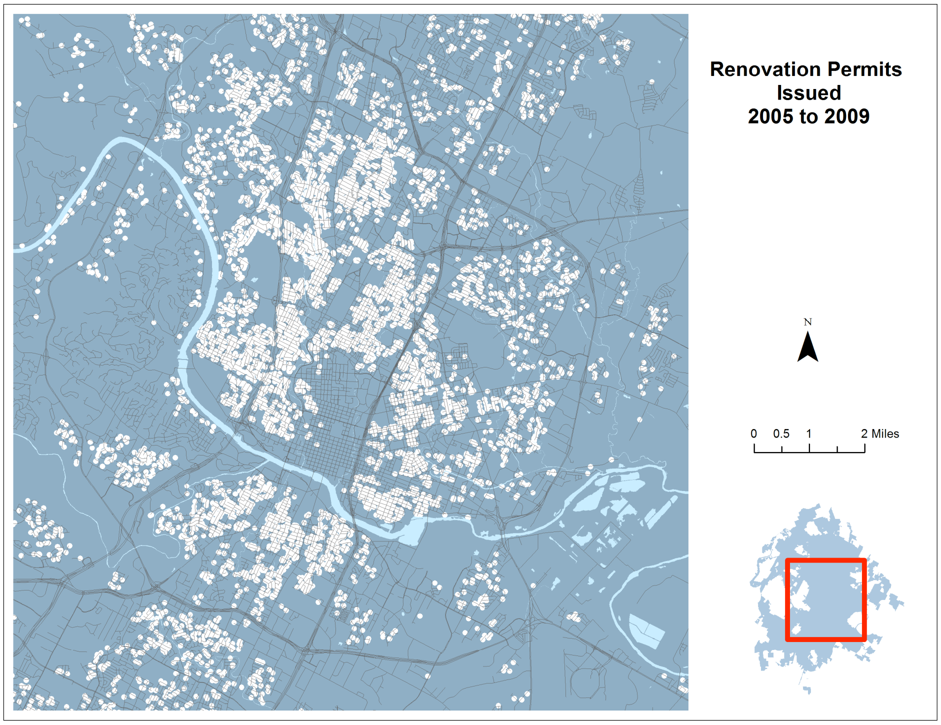


Figure 50 Renovation Permits 2005 to 2009



A more focused view of the density surface maps in Figure 47 is shown in **Figures 51** through **53** below. These figures provide a more informative visual than the point maps by illustrating and quantifying the density of renovation permits in downtown Austin.

Figure 51 Density of Renovation Permits 1995 to 1999

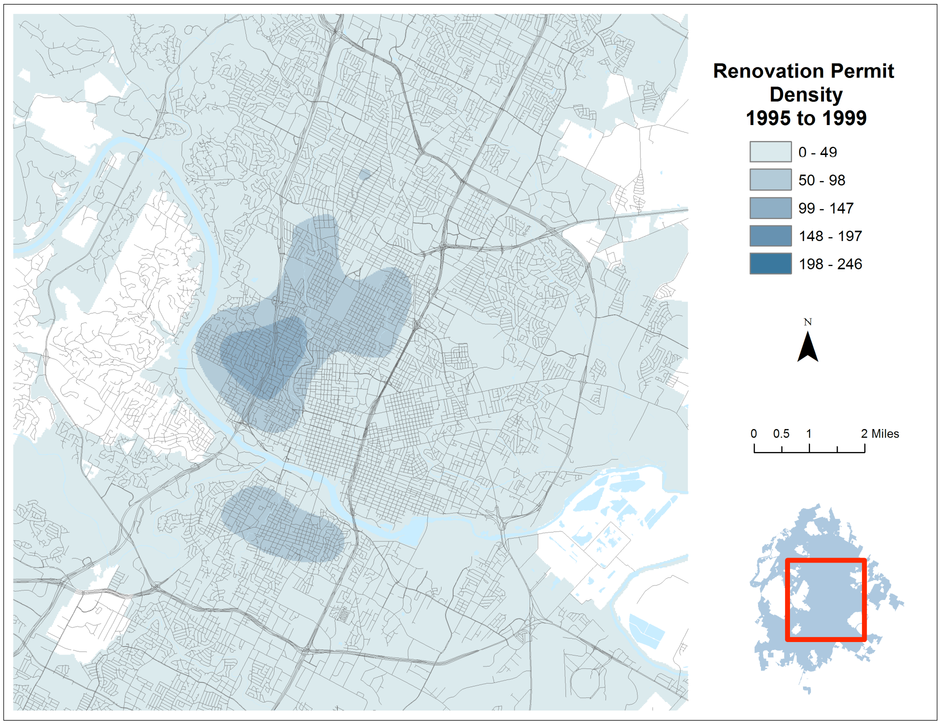


Figure 52 Density of Renovation Permits 2000 to 2004

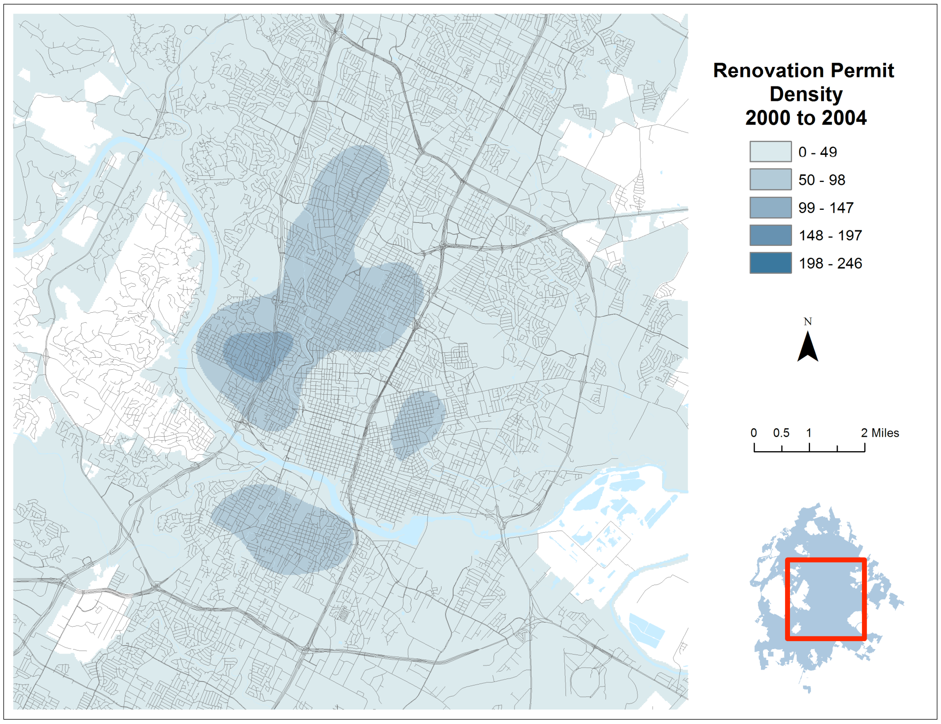
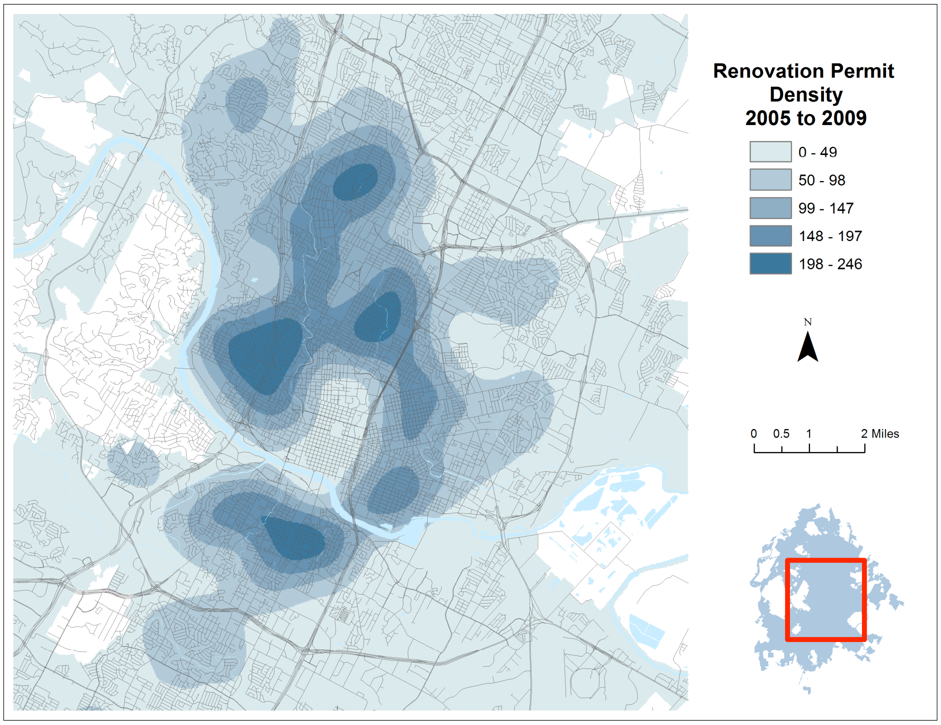


Figure 53 Density of Renovation Permits 2005 to 2009



In **Figures 54**, **55** and **56**, the dataset of renovation records was aggregated to census tracts for each of the three time periods analyzed. This provided another perspective to analyze trends, and also allowed for a more direct comparison of renovation permit data to traditional census indicators of gentrification.

Figure 54 Renovation Permits by Tract 1995 to 1999

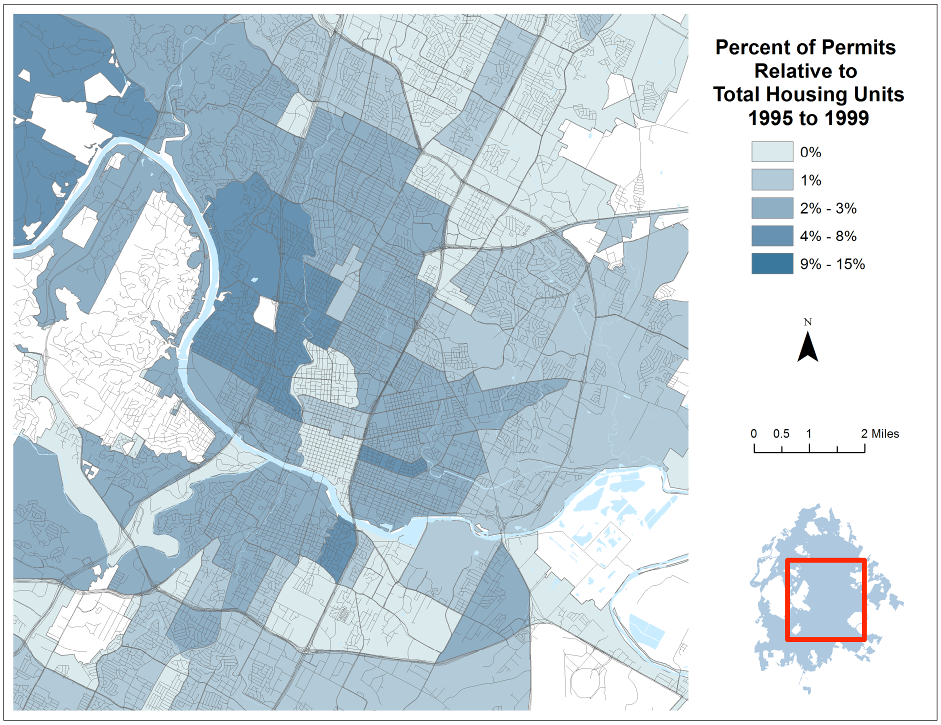


Figure 55 Renovation Permits by Tract 2000 to 2004

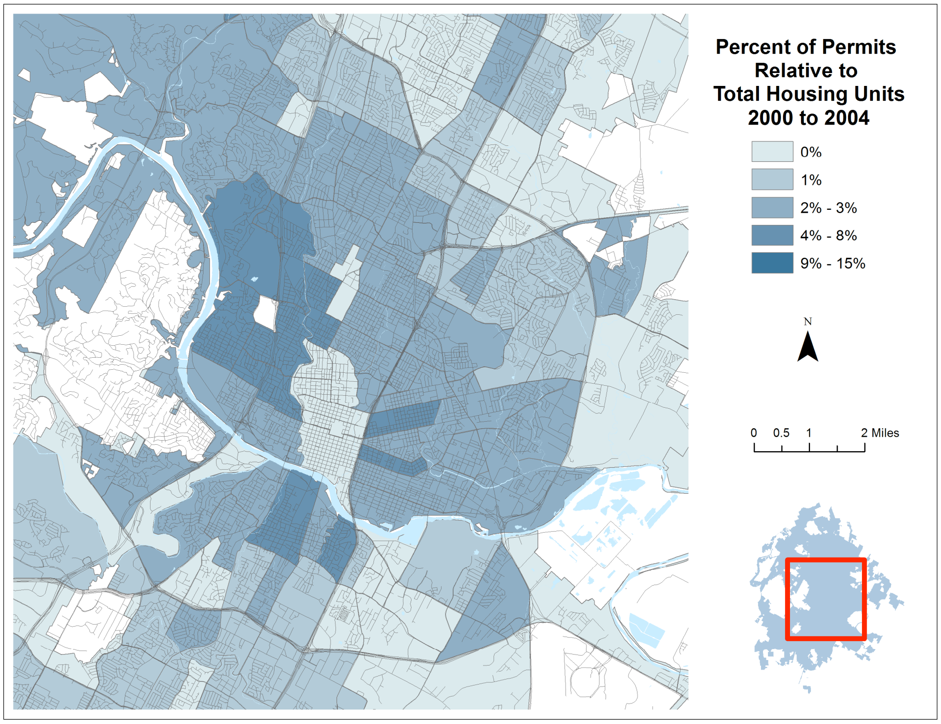
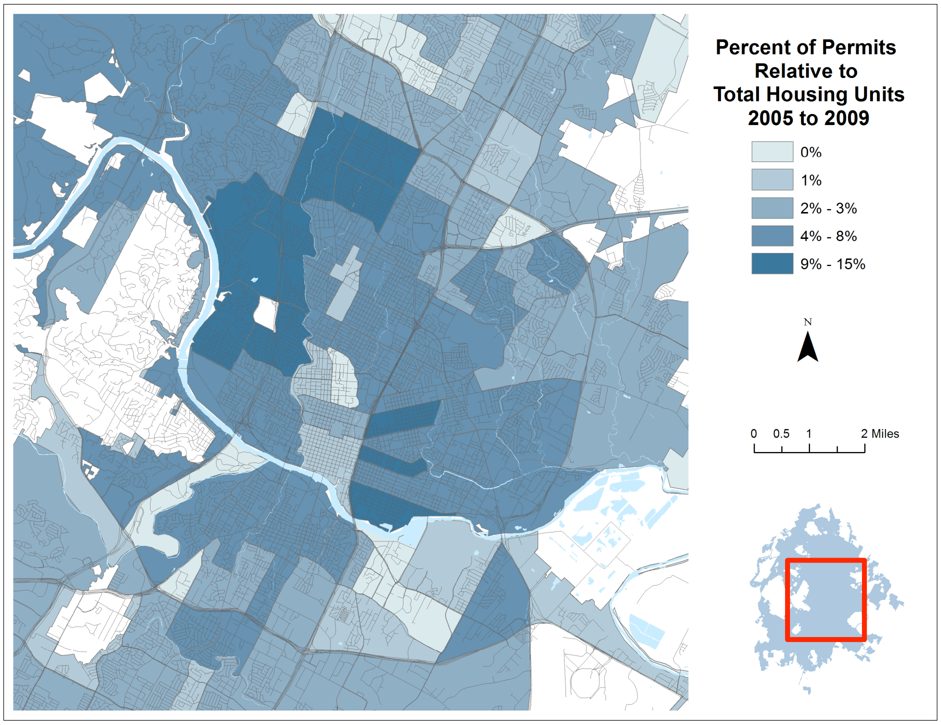


Figure 56 Renovation Permits by Tract 2005 to 2009



In order to compare the patterns generated by the building permit records, and to assess whether they may be tied to gentrification, traditional census indicators were mapped. Though there is no single category of data that, on its own, confirms an area is gentrifying, significant shifts in the racial makeup of a neighborhood very often accompanies this type of change. Race is primary amongst gentrification factors, and therefore maps of census data for the White, Hispanic and African American populations in Austin's urban core are shown in **Figures 57**, **58** and **59**.

Figure 57 Change in White Population 1990 to 2000

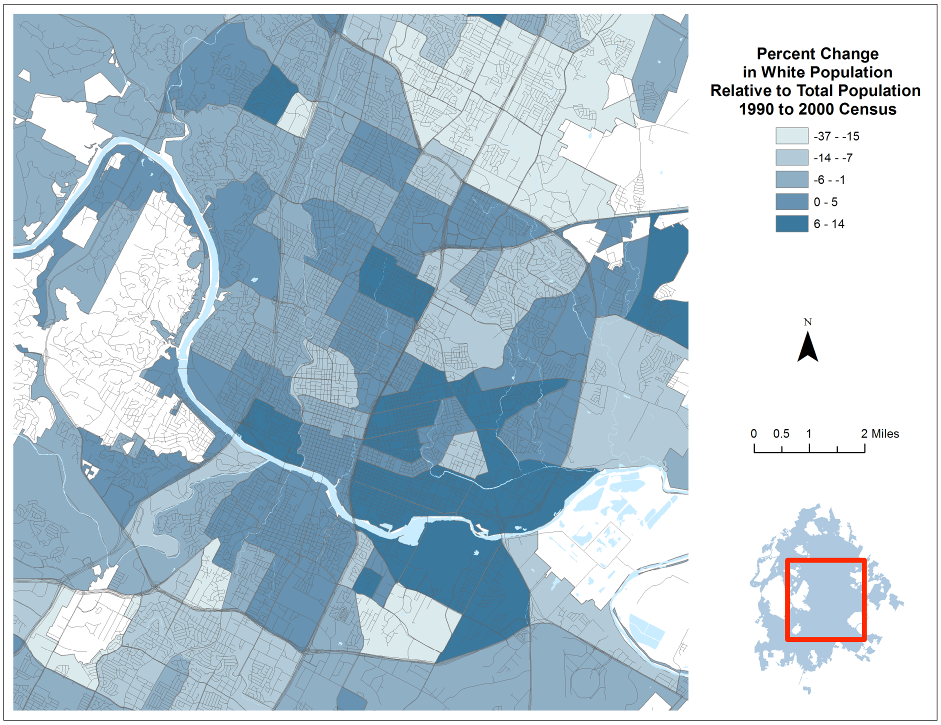


Figure 58 Change in Hispanic Population 1990 to 2000

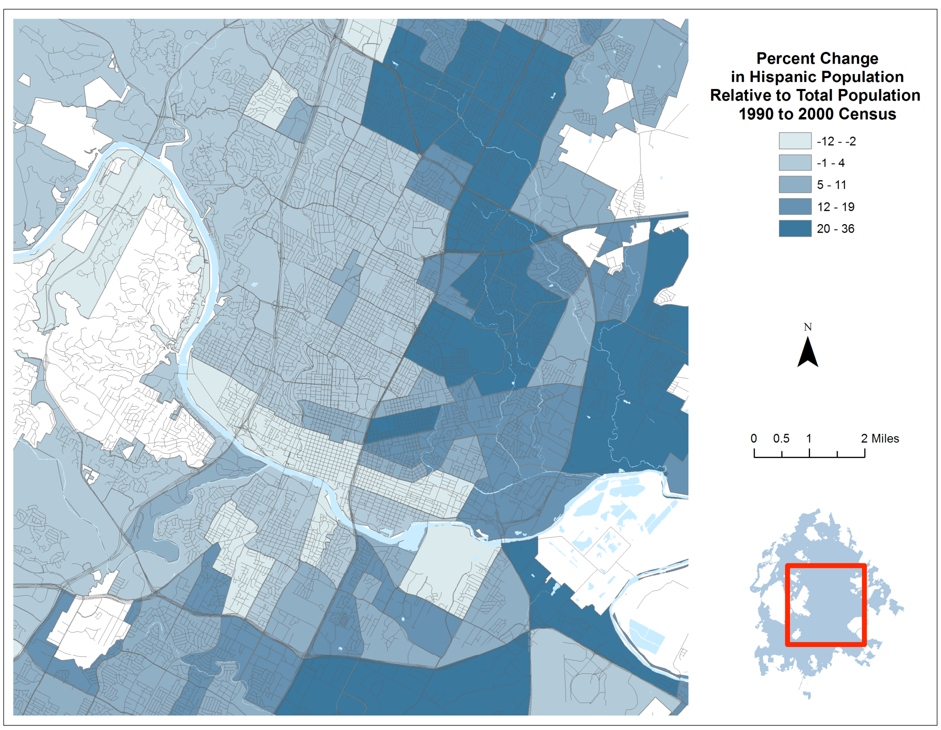
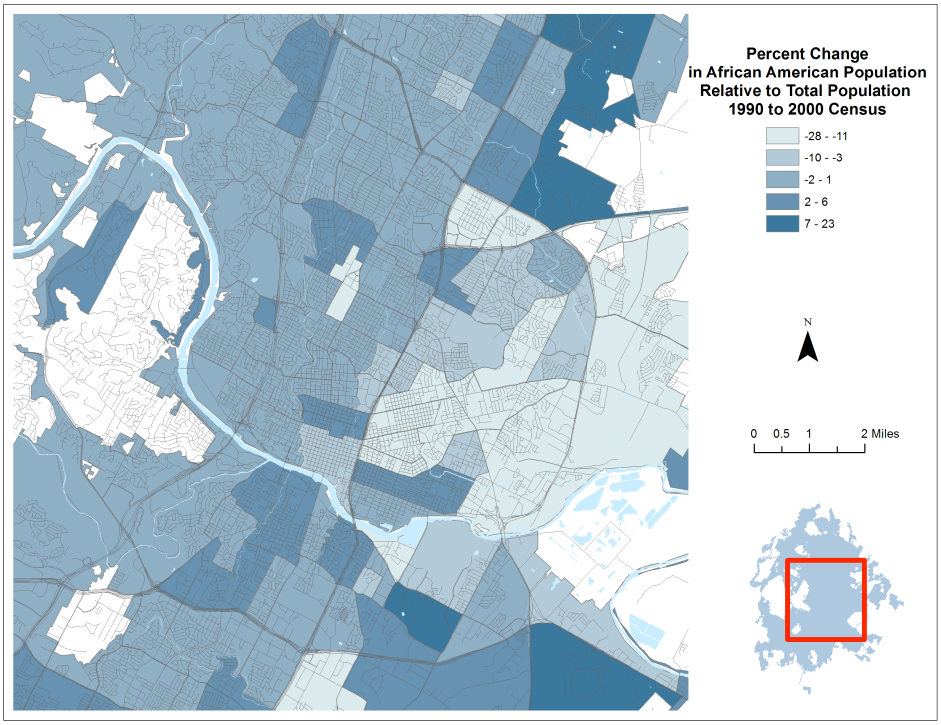


Figure 59 Change in African American Population 1990 to 2000



Gentrification in East Austin has been a widely acknowledge occurrence over the past few decades. The census race maps provided evidence of this, showing increases in the White and Hispanic populations in the traditionally African American area to the east of downtown. Concentrations of renovation permits were also evident in East Austin, supporting the hypothesis that this data may be used as an indicator of gentrification.

Overall, the permit maps in this section showed that renovations were happening most intensively around the urban core. These areas included, but were not restricted to census tracts that did not show drastic change in race variables. Besides being an indicator of gentrification, this provides evidence that renovation permit data could also indicate neighborhood change patterns across the city and through time in a way that could support more extensive analysis.

Chapter 7 Conclusions and Recommendation

My goal in this thesis was to spatially explore a data source, specifically building permits, that is not frequently used in visualizing land use trends. In this chapter, I have summarized what was gained through my research, drawing conclusion about the use of building permits with spatial analysis. Additionally, I have made recommendations regarding the most effective ways to structure building permit data for optimal use in assessing land development patterns.

7.1 Conclusions – Using Building Permit Data in GIS to Visualize Land Development Issues Over Time

Overall my purpose in comparing building permit data to various census products was to illustrate the differences between the local and national datasets, and to highlight some of the benefits of the city's dataset. Based on the factors of time, sample size and source of the data, I determined that the census data was different, sometimes significantly, from the local records. By placing visualizations of census data alongside of comparable maps of building permit data I showed that there are benefits related to geographic as well as temporal accuracy in using building permit records for land development analysis.

By performing spatial analyses of the BCP, SGI and gentrification, I demonstrated how building permits may be used to visualize information related to land development. I used characteristics of the building permit datasets, including unit count, housing size and value of construction, to provide varying perspectives of residential development trends within the city.

Times-series density surface map of building permits allowed me to illustrate the shifts of residential development relative to the BCP lands and when they were preserved. These maps did not numerically quantify these trends, but did provide useful visualizations. Further, by completing a multi-ring buffer analysis, I was able to quantify the permit data to show residential development statistics within set proximities to the conserved parcels.

For the part of my study involving the SGI, I illustrated trends over time relative to the DDZ areas and showed the differences in the permit data between specified years, including those when the initiative started and ended. I created these visualizations by performing another raster analysis using calculation functions on density surfaces. Additionally, aggregating the residential building permit data to the DDZ areas provided significant comparative information between development in DDZ areas versus overall in the City of Austin. Graphs and charts proved to be much more informative visualization of the resulting data than maps in this case.

When reviewing renovation data, my analysis showed that the local records did reveal clusters of permits in known areas of gentrification. This supported the hypothesis that renovation permit data could supplement traditional census gentrification indicators. Additionally though, my visualizations showed concentrations of renovation work in other areas around the urban core where gentrification was not thought to be occurring. This leads to the conclusion that renovation permits can show more than gentrification, they may be useful in investigating other neighborhood change and investment patterns across the city and through time.

In this study, I have explored the use of building permit records and GIS to investigate and present data related to land development. This thesis has attempted to demonstrate various spatial analysis techniques and reviewed the data available and steps necessary to perform an analysis. Through the course of my research, I learned what data was needed and the format it needed to be in in order to perform my assessments, as well as what could be done with available data. I explored options for aggregating, organizing and disseminating this information to maximize its utility and applicability.

7.2 Recommendations

As building permit records are a data source that every city is producing, data collection is not a hurdle to the use of this information for planning and policy-making purposes. However, the lack of availability and standardization of building permit databases across municipalities and over time was one of the primary challenges of this study. Therefore, I have designed a standard database template based upon the datasets and work done in this study and Austin's Residential Permit Application (AustinTexas.gov 2012). The recommended model includes a standard file format and key attributes with specific data requirements and consistent formats and codes. In addition to improving compatibility of data between municipalities, greater standardization in data formats, and especially in attributes, allows for increased ease of analysis and visualization.

7.2.1 Database Format

The first step to creating a standard is to determine a file format for storage of the data in order to ensure compatibility across municipalities and through time. One option is a point shapefile such as the ones that the City of Austin uses. In this format, all building permit data would be geocoded and ready for spatial analysis. However, requiring a geocoded file format for the building permit database may prove to be a burden on the resources of some municipalities, especially smaller towns or unincorporated areas that may lack funding or necessary technology resources.

Another format option for database design is to require the records be in a spreadsheet or database format such as Microsoft Excel or Access compatible files. These types of files are likely already ones maintained by most permit issuing agencies. In order to make this option more efficient, address information should be formatted in a specific way so that it could be easily geocoded to street-line shapefiles, and hence simplify the conversion of the permit information to a spatial format.

7.2.2 Key Attributes

Standardization requires identifying the key attributes and formats that all building permit databases include. **Table 5** lists the recommended attributes based on the research and data work performed in this study. Descriptions, examples and justifications of the attribute choices are included in the table.

Table 5 Recommended Key Attributes for Standard Building Permit Database

Attribute	Description	Examples	Justification
PermitNo	Building permit number serving as a unique identifier for each record	123456	A unique ID is necessary to effectively organize, track and analyze the data.
Lat	Latitude	30.30	This is a standardized and precise location indicator that is increasingly available through GPS and online mapping.
Long	Longitude	97.70	This is a standardized and precise location indicator that is increasingly available through GPS and online mapping.
ParcelID	Tax parcel identification number	02-3415-06-02	This provides an additional standardized unique identification.
Zoning	Zoning designation for parcel where permit is requested	SF-1, SF-2, etc.	Zoning specifies requirements and allowances for designated areas, providing additional information about permitted structures.
ServiceAdd	Street address for which permit is requested	123 Main Street	Address-related data is necessary for geocoding the file to local or Census TIGER street files.
Apt	Apartment number for which permit is requested, if applicable	1, 2A, etc.	Address-related data is necessary for geocoding the file to local or Census TIGER street files.
City	City where permit is requested	Austin	Address-related data is necessary for geocoding the file to local or Census TIGER street files. Additionally, Location data is useful for aggregation to various geographies.

Attribute	Description	Examples	Justification
State	State where permit is requested.	TX	Address-related data is necessary for geocoding the file to local or Census TIGER street files. Additionally, Location data is useful for aggregation to various geographies.
County	County where permit is requested	Travis	Location data is useful for aggregation to various geographies.
ZipCode	Five-digit USPS zip code where permit is requested.	73301	Address-related data is necessary for geocoding the file to local or Census TIGER street files. Additionally, Location data is useful for aggregation to various geographies.
OwnLName	Last name of the parcel owner	Smith	Data feature useful for identification and organization in records.
OwnFName	First name of the parcel owner	John	Data feature useful for identification and organization in records.
BuildCo	Builder company name	Build, Inc.	Data feature useful for identification and organization in records.
BuildReg	Builder’s state registration number	9876543	Data feature useful for identification and organization in records.
SubDate	Date that the building permit application was submitted. The format of this parameter is mm/dd/yyyy.	01/15/2008	Timing information is important as the continuous nature of the dataset is one of the major benefits of using such records.
IssueDate	Date that the building permit was issued. The format of this parameter is mm/dd/yyyy.	02/19/2008	Timing information is important as the continuous nature of the dataset is one of the major benefits of using such records.

Attribute	Description	Examples	Justification
Year	Year that the building permit was issued.	2008	Timing information is important as the continuous nature of the dataset is one of the major benefits of using such records.
Type	Type or category of the work that the building permit is requested for	new residence, remodel, renovation, addition, other	Including a project type or category is essential to organizing the data and allowing users to extract the information that is pertinent to their work.
WorkDesc	Description of the work that the building permit is requested for, including any important notes or details	structure part of larger subdivision project	Including a work description allows for fuller information or miscellaneous details to be recorded that is not captured in other attributes but may be pertinent to analysis work.
Status	Status of the permit application	active, final, withdrawn, void	Including permit status allows for sorting and organization of data records for analysis.
Subdiv	Indicator of whether the structure that the permit is requested for is part of a subdivision. The value of this parameter can be "y" or "n".	y or n	This is a useful feature for grouping records for analysis.
ResType	Indicator of the type of residence – single or multi-family	single or multiple	This is a useful feature for grouping records for analysis.
NoHU	Number of housing units proposed for parcel	1, 2, 3, etc.	This was a primary characteristic assessed in this study and determined to be useful in spatial analysis.
LotArea	Size of proposed building lot measured in gross square feet	4000	This is a detailed piece of data that could prove useful in visualization and analysis.

Attribute	Description	Examples	Justification
FloorArea	Size of proposed structure measured in gross square feet	3500	This was a primary characteristic assessed in this study and determined to be useful in spatial analysis.
Height	Height of proposed building in feet	24	This is a detailed piece of data that could prove useful in visualization and analysis.
NoFloors	Number of floors in proposed building	1, 2, 3, etc	This is a detailed piece of data that could prove useful in visualization and analysis.
Valuation	Total projected cost of project construction in U.S. dollars	300000	This was a primary characteristic assessed in this study and determined to be useful in spatial analysis.
OccPermit	Indicator of whether an occupancy permit was issued. The value of this parameter can be "y" or "n".	y or n	This is an important indicator of whether the permitted structure was completed.
OccDate	Date that an occupancy permit was issued, if applicable. The format of this parameter is mm/dd/yyyy.	10/16/2009	This is an important indicator of whether and when the permitted structure was completed.

7.2.3 Data Quality and Completeness

Many municipalities record more data fields than those that I have recommended. Austin's data files, for example, contained up to 62 columns of attributes for their permits including contact information for the applicant and fields for geocoding purposes. Additionally, there are fields with more detailed usage and work descriptions as well as information on subdivisions and things specific to Austin including identification numbers and indicators related to Desired Development and Smart Growth Zones. The information I have recommended should be kept in order to aid land development analysis, however individual municipalities may continue to add attribute fields necessary for their use and records.

Missing and improperly formatted data can cause extra data cleanup steps. In this study, Austin's building permit data was found to be comprehensive and overall consistent, however, it does have missing information and discrepancies in the data fields recorded over time that required cleanup. Further there were often blank cells when a field was inapplicable for a record. For instance, the area attribute for a demolition permit. In order to mitigate issues caused by inconsistent data, standard abbreviations and codes should be adhered to. Additionally, all fields should be completed, "N/A" being used when a field is not applicable.

7.3 Summary

It is clear that there are challenges to using building permit data for GIS visualizations and analysis of land use concerns. Primary amongst these challenges are the time, effort and collaboration needed to standardize the records and make them a reliable and consistent data source.

However, this study has also shown that there are great benefits to using building permit records in planning research. The data enables researchers to view and analyze information related to housing and land development in ways beyond those of other resources. Building permit records allow land development analysis at a fine level of spatial detail, down to a specific street address point, providing researchers with the ability to view patterns at various geographic levels and user-defined areas. Additionally, because building permit records comprise continuous datasets, data and patterns can be tracked or viewed by year, quarter, month or even day of permit issuance. The fine level of geographic and temporal detail that building permit records contain enables the use of raster analysis techniques in GIS which allow for more accurate observations of geographic trends and time-lapsed patterns. Finally, use of building permit records provides attributes to review that are not available from traditional land use data sources. This information can help expand the analysis capabilities and data cache related to land development.

References

Allen, J. & Lu, K. & Potts, T. (1996). A GIS-based analysis and prediction of land-use change in a coastal tourism destination area. Retrieved October 2010 from http://nsgl.gso.uri.edu/washu/washuw99003/29-Allen_et_al.pdf

American Planning Association. (2002). Growing Smart Legislative Guidebook: Model Statutes for Planning and the Management of Change, 2002 Edition. Retrieved from http://www.planning.org/growingsmart/guidebook/print/index.htm

Austin City Connection. (2010). *Growth Watch*. Retrieved October 2010 from http://www.ci.austin.tx.us/growth/.

Austin City Connection. (2011). *Frequently Asked Questions*. Retrieved July 2011 from http://www.ci.austin.tx.us/development/onestop/faqs.htm.

Beauregard, R. A. 2009. Urban population loss in historical perspective: United States, 1820–2000. *Environment and Planning A* 41, pages 514-528.

Choi, S. & Wang, P. & Delgado, E. & Ryu, S. (2007). Monitoring Small Area Growth with GIS: An Application to the City of LA. Paper presented at the 2007 ESRI International User Conference, San Diego, California, June 18-22, 2007. Retrieved October 2010 from http://www.scag.ca.gov/forecast/downloads/paper/esri07.pdf

Christie, L. (2007). The fastest growing U.S. cities - From the Empire State to the Lone Star State - the cities that are growing the most. *CNNMoney.com*. Retrieved June 2011 from http://money.cnn.com/2007/06/27/real_estate/fastest_growing_cities/

City of Austin. (2010). City of Austin GIS Data Sets. Retrieved October 2010 from ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html.

City of Austin. (2012). Planning and Development Review Department: Forms and Applications. City of Austin Residential Permit Application. Retrieved February 2012 from: http://www.austintexas.gov/sites/default/files/files/Planning/Applications_Forms/residential_permit_app.pdf

City of Austin. (n.d. a). City of Austin's Anonymous FTP Server. Retrieved October 2010 from ftp://ftp.ci.austin.tx.us/GIS-Data/planning/data/.

City of Austin. (n.d. b). City of Austin's Anonymous FTP Server. Retrieved October 2010 from ftp://ftp.ci.austin.tx.us/GIS-Data/planning/GIS/.

City of Boston. (2010). Building Permit Search. *Inspection Services Department*. Retrieved June 2011 from http://www.cityofboston.gov/isd/permitsearch/default.aspx

City of Boulder, Colorado. (2011). Austin, Texas Smart Growth Initiative. Retrieved from http://www.bouldercolorado.gov/files/Transportation_Master_Plan/Smart_Growth_Matrix_program.pdf

City of Dallas, Texas. (2001-2006). Building Construction. *Sustainable Development and Construction*. Retrieved June 2011 from http://www.dallascityhall.com/building_inspection/index.html.

Coulton, C. (2008). Administrative Data Sources for Neighborhood Indicators. The Urban Institute. Retrieved October 2010 from http://www.urban.org/UploadedPDF/411605_administrative_data_sources.pdf

ESRI. (2011). How Kernel Density Works. *ArcGIS Resource Center*. Retrieved March 2012 from http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/How_Kernel_Density_works/009z00000011000000/

ESRI. (2012). *GIS Data Dictionary*. Retrieved March 2012 from http://support.esri.com/en/knowledgebase/GISDictionary/term/centroid

Farmer, P. (2005). Life in The Big City: What Is Census Data Telling Us About Urban America? Are Policymakers Really Listening?. Retrieved February 2011 from http://www.esri.com/industries/planning/docs/paul_farmer_census.pdf

InflationData.com. (2011). Inflation Calculator. Retrieved July 2011 from http://inflationdata.com/inflation/Inflation_Calculators/Inflation_Calculator.asp.

Logsdon, M. & Bell, E. & Westerlund, F. (1996). Probability Mapping of Land Use Change: A GIS Interface for Visualizing Transition Probabilities. Computers, Environment and Urban Systems, 20(6), 389-398. Retrieved October 2010 from http://www.sciencedirect.com/science/article/pii/S0198971597000045

MacDonald, H. (2008). City Planning and the U.S. Census: 1910 to 1960. Journal of Planning History, 7(4), 263-294 doi: 10.1177/1538513208315847

MacDonald, H. & Peters, A. (2011). *Urban Policy and the Census*. Redlands, CA: Esri Press.

Marker, D. (2001). Producing Small Area Estimates From National Surveys: Methods for Minimizing use of Indirect Estimators. Survey Methodology, 27(2), 183-188. Retrieved October 2010 from http://www.statcan.gc.ca/ads-annonces/12-001-x/4225278-eng.pdf

Mennis, J. (2003). Generating surface models of population using dasymetric mapping. The Professional Geographer 55: 31-42. Retrieved from http://astro.temple.edu/~jmennis/pubs/mennis_pg03.pdf

NCSU (North Carolina State University) Libraries. (n.d.). Census Geographies. Numeric Data Services. Retrieved June 2011 from http://www.lib.ncsu.edu/data/censusgeography.html

Proximity (2011). *Census Tract Demographic Patterns*. Retrieved October 2011 from http://proximityone.com/tracts.htm

Sadahiro, Y. (1999). Accuracy of Areal Weighting Interpolation: Effects of Geometrical Properties of Zonal Systems. Center for Spatial Information Science and Department of Urban Engineering, University of Tokyo. Retrieved October 2010 from http://www.csis.u-tokyo.ac.jp/dp/10.pdf

Sawicki, D. & Flynn, P. (1996). Neighborhood Indicators: A Review of the Literature and an Assessment of Conceptual and Methodological Issues. Journal of the American Planning Association, 62(2), 165-183. doi: 10.1080/01944369608975683

Smersh, G. & Smith, M. & Schwartz A. (2003). Factors Affecting Residential Property Development Patterns. Retrieved October 2010 from http://findarticles.com/p/articles/mi_qa3750/is_200301/ai_n9188829/

Smith, S. & Morrison, P. (2005). Small-Area and Business Demography. chapter 25 in Dudley Poston and Michael Micklin (eds.), Handbook of Population. New York: Springer Publishers. Retrieved October 2010 from http://www.bebr.ufl.edu/files/SmallArea_Bus_Demog_0.pdf

Smith. S. (2003). Small-Area Analysis. pages 898-901 in Paul Demeny and Geoffrey McNicoll (eds.), Encyclopedia of Population. Farmington Hills, MI: Macmillan Reference. Retrieved October 2010 from http://www.bebr.ufl.edu/files/Pop_Encycl_Small_Areas_0.pdf

The City of New York. (2012). NYC Buildings. Retrieved March 2012 from http://www.nyc.gov/html/dob/html/bis/bis.shtml

The Nature Conservancy (2010). Conservancy and Austin to Expand Barton Creek Wilderness Park: Purchase of key inholding will protect wilderness slated for commercial development. *The Nature Conservancy*. Retrieved October 2010 from http://prod.nature.org/ourinitiatives/regions/northamerica/unitedstates/texas/newsroom/conservancy-and-austin-expand-parklands.xml

Travis County, Texas. (2010). Retrieved October 2010 from http://www.co.travis.tx.us/tnr/default.asp

Travis County, Texas. (2011). *Transportation and Natural Resources*. Retrieved July 2011 from http://www.co.travis.tx.us/tnr/default.asp

Tu, W. & Li, L. & Piltner R. (2005). A Study of Smart Growth Initiatives using GIS: The case of Austin, Texas. Retrieved October 2010 from http://www.digitalgovernment.org/library/library/dgo2005/postersa/tu_study.pdf

U.S. Census Bureau. (2010). A Data-Filled Day – September 16, 2010. *Director's Blog*. Retrieved October 2011 from http://directorsblog.blogs.census.gov/2010/09/16/a-data-filled-fall/

U.S. Census Bureau. (2011a). *American Community Survey*. Retrieved June 2011 from www.census.gov/acs/www/

U.S. Census Bureau. (2011b). *American FactFinder*. Retrieved February 2011 from http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

U.S. Census Bureau. (2011c). *Building Permits*. Retrieved June 2011 from http://censtats.census.gov/bldg/bldgprmt.shtml

U.S. Census Bureau. (2011d). How to use Microsoft Access to extract data from the 2010 Census P.L. 94 - 171 Summary Files. *Redistricting Data*. Retrieved June 2011 from http://www.census.gov/rdo/pdf/0HowToUseMicrosoftAccessShells.pdf

U.S. Census Bureau. (2012). *History: Decennial Census*. Retrieved March 2012 from http://www.census.gov/history/www/programs/demographic/decennial_census.html

Wilson, R., Rhodes, L. & Glickman, N. (2007). Community Change in East Austin. Policy Research Project Report, Number 160. Lyndon B. Johnson School of Public Affairs, University of Texas at Austin.