Exploring Land Use Changes in the City of Irvine's Master Plan

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To my parents, Carroll and Karen Goldsworth

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List of Abbreviations

GIS	Geographic information system
HGIS	Historical geographic information systems
IBC	Irvine Business Complex
UCI	University of California at Irvine

Abstract

The City of Irvine is one of the largest and earliest planned communities in the United States. It began in the 1960s after the University of California agreed to put their newest campus on land in the Irvine Ranch. The Irvine Company developed a General Plan for a small city of 10,000 people around the university but eventually expanded that plan to include the entire 100,000-acre Irvine Ranch. Many New Towns movement principles were followed. When the city incorporated, the new city council did not start from scratch but built upon the Irvine Company's master plan. This area was unique for a planned community in that it was huge, mostly undeveloped, and mostly under one landowner.

GIS is used in this study to digitize and compare the 1973 General Plan of the Irvine Company with the 2017 land use database to determine if and where land use changes have taken place. Current parcel data was compared with the 1973 Irvine Company General Plan map to enable the tracking of changes for each parcel, if any. Extract Values to Points was used to pull values from the historical map into the current land use database. A pivot table was used to build a matrix of land use change pairs. The first research objective was to compare these two maps and locate changes. The second research objective is to see whether there are any trends in land use changes. This study found an increase in the amount of land dedicated to Open Space and a surprising decrease in residential density in a few parts of Irvine. Also found was a new trend in land use where residential units are being built inside the Irvine Business Complex. The resulting database could be used for future studies concerning one of the biggest and oldest planned communities in the United States.

Chapter 1 Introduction

Irvine is a large city in the middle of Orange County along the southern coast of California. Beaches are close by to the southwest and foothills close by to the northeast. Two big centers of culture, Los Angeles and San Diego are just an hour's drive away. The City of Irvine is outstanding for many reasons. It has been named one of the Safest Cities in America for 11 years in a row (de Crescenzo 2015) and the schools are ranked among America's best (Irvine Unified School District 2016). Irvine is known for its 57,000 acres of wildland preserves, hiking and biking trails, open space, and numerous parks including the Great Park which draws visitors from all over the county.

This project looks at the history of Irvine as a master planned community and how the land use element of the General Plan may have changed. Irvine was originally planned by architect William Pereira using New Town principles. A geographic information system (GIS) is used to extract information from an historic map and analyze comparisons with current land use. Other elements of the General Plan such as transportation or waste management are not part of this study, only the land use element.

Chapter One gives a brief background for this study. The history section explains how Irvine was transformed from one huge land parcel into a city. Basic principles of the New Towns urban planning movement are then touched on. The study area section puts the city of Irvine in geographic context and the final section explains the goals of this study.

1.1. History

The written history of Irvine begins with Alta California and the King of Spain. Juan Rodriguez Cabrillo claimed what is now California for Spain in 1542. Spain claimed all of what is now Mexico and the western United States. Between 1784 and 1821, Spain issued 16 land

grants in California. When Mexico won independence in 1821, the new country issued over 600 land grants to individuals (US General Land Office 1886).

James Irvine came to California during the Gold Rush where he and two partners bought some of the Spanish/Mexican ranchos in Southern California. The first ranchos were large grants of land often granted to the men who had helped Spain explore California. The Rancho Santiago de Santa Ana was granted by the Spanish King to Jose Antonio Yorba and Juan Pablo Peralta in 1810 and confirmed by Governor Arrillaga of Mexico after that country won independence from Spain (Cleland, 1966). Mexico granted the deeds for the Rancho Bolsa de San Joaquin to Jose Andres Sepulveda in 1842 and the Rancho Lomas de Santiago to Teodosio Yorba in 1846. By 1876, James had bought out his partners and become sole owner of the 101,026-acre Irvine Ranch created from these three ranchos. James Irvine believed that land was wealth and that one should never sell land. In 1886, "land baron James Irvine traded his 108,000-acre ranch for a six-foot plot," as the Irvine Company's Historian Jim Sleeper (1973, 85) put it.

James Irvine II took over at a time when Southern California was undergoing significant change. When the County of Orange was founded in 1889, the Irvine Ranch represented nearly 25% of the new county's 786 square miles (Brower 1994, 4). In 1894, James Irvine II incorporated the ranch lands as the Irvine Company, cut back on cattle ranching, and expanded growing food crops. The ranch produced oranges, avocados, walnuts, sugar beets, and olives. By 1911, Irvine was the world leader in producing lima beans (D. Kane 1996).

The founding of the city of Irvine begins in part with the University of California. In 1957, with the population Orange County growing rapidly, the University of California was looking to build a new campus in the county. It chose a site on the Irvine Ranch. It hired the architect William Pereira to plan the new campus and a surrounding university town, both on

Irvine Ranch lands. Pereira envisioned the college town to go with the new university based on ideas he learned from studying other great university towns like Oxford and Heidelberg (Forsyth 2005). Some of the characteristics of a great university are a location close to an urban center, faculty and student housing nearby and a physically attractive location (D. Kane 1996).

With the population explosion after WWII, the need for housing in Southern California created a great opportunity for the Irvine Company, which shifted from an agricultural concern to a real estate developer. It hired William Pereira to design residential tracts, and in 1966 and 1967 the villages of University Park and Turtle Rock were built (Bell 2011). At the time, nearby cities in Orange County, including Santa Ana and Tustin were looking to expand their boundaries. To stop other cities from annexing Irvine Ranch land, the Irvine Company and the residents of its newly built villages sought to incorporate.

Pereira created a master plan for the entire Irvine Ranch. He laid out a planned city according to New Town Movement principles. In February of 1971, the County of Orange Planning Commission accepted the master plan, and in December of 1971 the City of Irvine was incorporated (D. Kane 1996). Figure 1 shows the boundaries of the City of Irvine at incorporatino in 1971, the Irvine Ranch, and Orange County.

Figure 1 The City in 1971, the Irvine Ranch and Orange County

1.2. The New Town Movement

The New Town movement focused on building a community that provided for a full range of human needs: a variety of housing, nearby employment, education, shopping, recreation, open space, and culture. There was to be a balance of jobs and workers in varied occupations, different economic and social groups, and attention paid to preserving open space (Watson 1964). The structure is often several villages, each providing all these services, with several villages together forming the city. Irvine functions as a collection of villages each with its own shopping center so residents need not travel far for groceries or basic services. There are

twenty-five villages in Irvine. Two of the biggest villages are Woodbridge, with around 25,000 residents, and Turtle Rock, with about 10,000 residents.

The idea behind the villages concept is that each should be an identifiable unit and should create a strong sense of place. Each village has a distinct character because of the landscaping, signs, gateways, architectural styles and natural features such as berms or waterways. The villages of Irvine connect to form a city via a grid of wide tree-lined avenues. One of the principles of the New Town movement that did not survive is the plan for a mass-transit system across the center of the city, gathering the residents from the center and taking them to jobs in the business parks on either side of the city.

1.3. Study Area

At incorporation, in 1971, Irvine was 28.3 square miles with a population of 20,156. By 2016, the area had grown to 66.6 square miles and the population expanded to 258,386 (City of Irvine 2016b). Pereira's original estimate for the Irvine Ranch was for a final population of around 400,000 residents.

The land use baseline for this study is the Irvine Company's 1973 General Plan for the entire Irvine Ranch at that time, which was about 100,000 acres. The City of Irvine incorporated at the end of 1971 where the boundaries of the planning area encompassed only the City and its sphere of influence. The sphere of influence is the area over which the City has some degree of influence. It represents the potential boundaries of the City which have been agreed to by the Local Agency Formation Commission and by adjacent cities (City of Irvine 1984, i).

By December 1973, the 1973 General Plan covered far more land than was included in the Irvine city limits at the time of incorporation. "The planning area…consists of the incorporated area of the City of Irvine, the sphere of influence defined for Irvine by the Local

Agency Formation Commission and the coastal region of the Irvine Ranch" (Wilsey and Ham 1973, i-3). This planning area was described as 100 square miles. (Wilsey and Ham 1973, 2-31). It included the Coastal Region which was later dropped from the planning area. In 1977, the official planning area can be seen extending northeast into the foothills (Figure 2).

The City of Irvine has made over 30 annexations and detachments of land since incorporation. There have been annexations and detachments of less than an acre and there have been large annexations. All this activity has grown the city from 28.184 square miles to 66.001 square miles. The land use database from the City of Irvine used in this study covers the entire sphere of influence - 74 square miles. The city's demographics website says the incorporated area is 66 sq. mi. and the sphere of influence is 74 sq. mi. (City of Irvine 2016b). The sphere of influence is the white area inside the blue City limits (Figure 3) in the map from the Orange County Local Area Formation Committee(OCLAFC 2008). The entire 8 square miles inside the sphere of influence, but outside the incorporated city, is coded as Open Space.

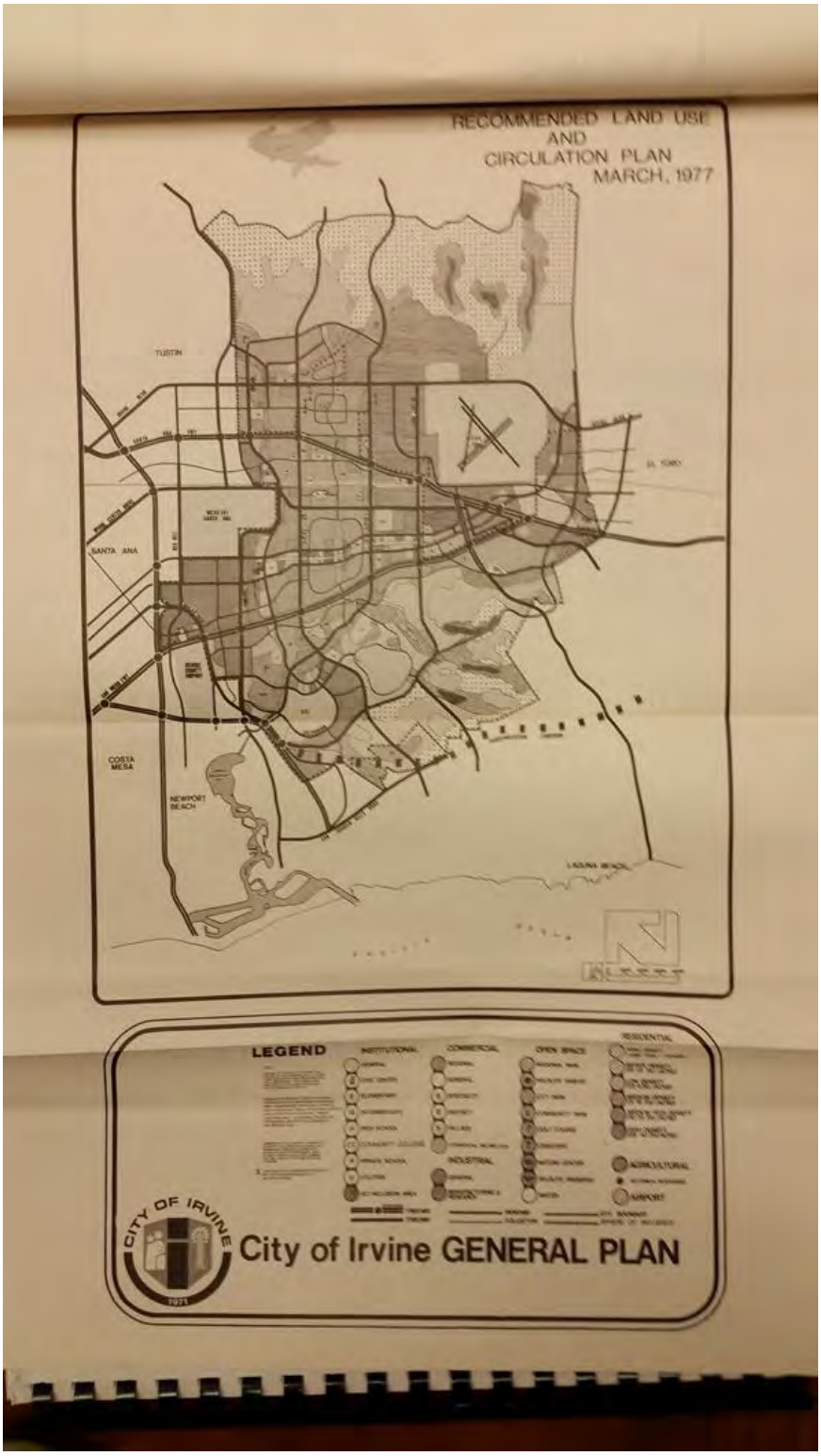

Figure 2 The Recommended Plan of 1977

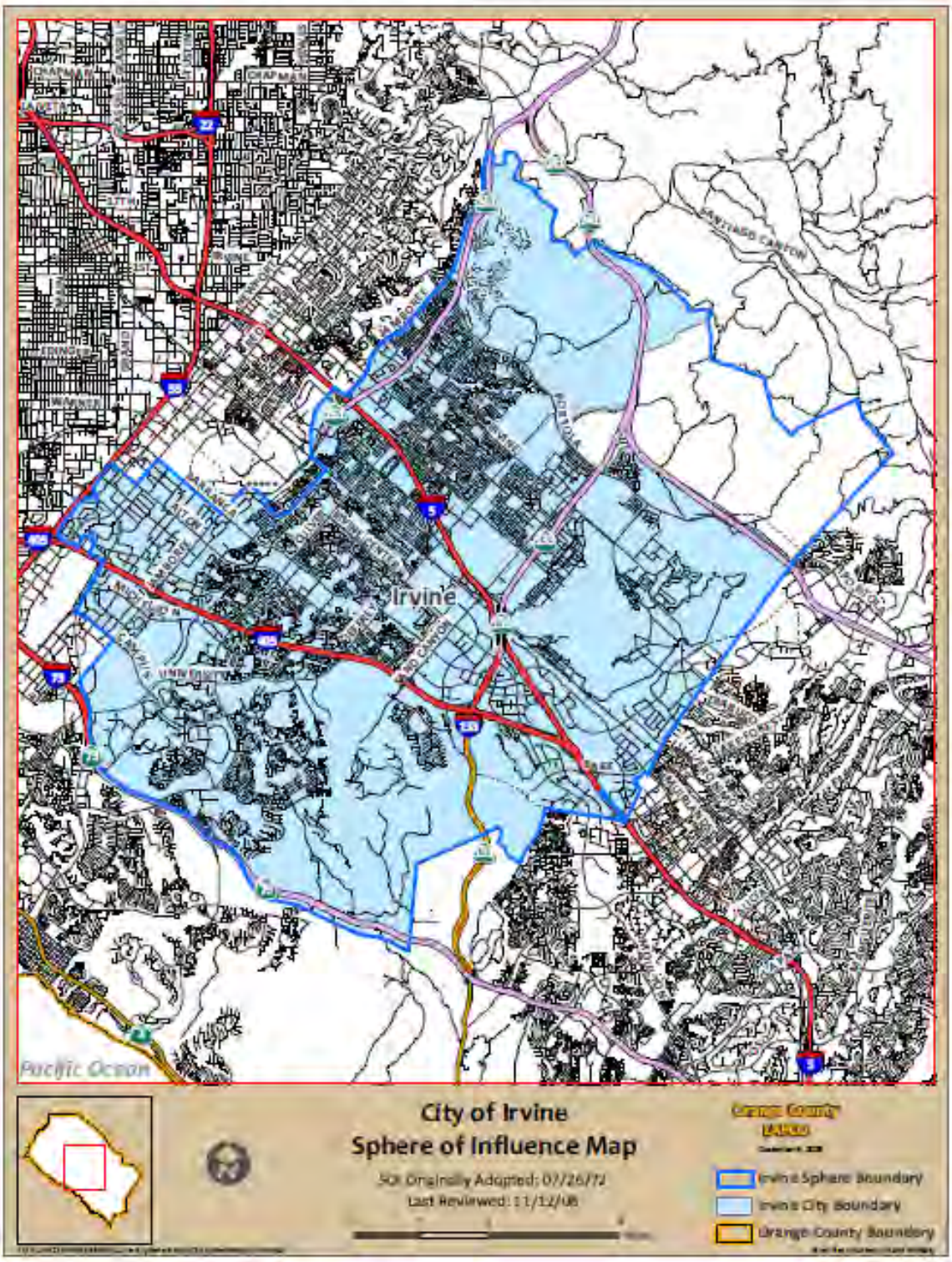

Figure 3 The Incorporated City versus the Sphere of Influence

1.4. Research Goals and Methods

This study explores the land use changes in the City of Irvine, California using a historical map, a current parcel database, and GIS. Surprisingly, extensive research found no other studies where GIS has been used to study and quantify land use changes over a long historical period from a community's original master plan. Researchers interested in the development of Irvine might like to know if there have been many changes to the original General Plan for Irvine since it became a city in 1971 or has the master plan been followed exactly.

The General Plan map from 1973 was chosen because it is the earliest, dated, General Plan land use element map available after the incorporation of the city at the end of 1971. The 2017 parcel data with land use codes was acquired on January 27, 2017 from the GIS department at the City of Irvine. The spatial and temporal scales of this study are limited to the City of Irvine in 1971 and two years, 1973 and 2017.

The research question is whether the current land use in the City of Irvine matches the intended land use for Irvine as evidenced in the Irvine Company's 1973 General Plan. To find parcels where the current land use is different from the plan in 1973, an image of the 1973 General Plan map of the Irvine Ranch was imported into ArcMap and georeferenced. A parcel map from the City of Irvine was used to extract land use codes from the 1973 map to one centroid point in each parcel of the City of Irvine layer. Then the land use codes were compared to see which parcels had a change of land use between the two years' General Plans. Tracking those changes with a geographical information system helps to quantify, describe, and visualize those changes.

Chapter 2 Background and Literature Review

The City of Irvine and the New Towns movement have been studied numerous times. Irvine has been looked at as a master planned community, one of the first and largest in the US. The original General Plan for Irvine was based on New Towns principles such as shops and services being nearby in the local village. This study pulls information from an old map to compare with current data to help develop the narrative of the City of Irvine. GIS, as a tool, can add to the historical narrative for a specific place (Raymond 2011).

2.1. Irvine in the Spotlight

The master planned community of Irvine is a valuable opportunity as a case study because it was one of the first and largest master planned communities. The original Irvine Ranch had over 100,000 acres which gave planners a huge blank canvas to work with and it was all under one owner, the Irvine Company. Ray Watson (1964) believed the City of Irvine was internationally known as the most successful New Community of the century. Almost all the New Town projects of the 1960s and the 1970s went bankrupt (Garreau 1991). Irvine, however, is one New Town project that not only survived but is growing continuously.

Irvine as a planned community has been studied extensively since the 1960s. It was part of the National Science Foundation's New Communities USA study by sociologists Burby and Weiss in 1976. Burby and Weiss reported that, regardless of planned or unplanned communities, residents appreciated neighborhood pools, utilities being underground, and culs-de sac. Irvine rated well in resident satisfaction in this study because of the design and planning, the extensive and varied landscaping, and the recreational facilities nearby. Diane Kane's (1996) study compared two of what she considered to be the most successful 1960s New Towns, Westlake and Irvine, both in California. Kane delved deeply into the politics behind creating both

communities and at their adherence to New Town principles. Ann Forsyth (2005) compared the success of Irvine with two other New Town developments in 2002 and detailed their development in a book. She compared the Irvine Ranch development with the planned communities of Columbia in Maryland and The Woodlands in Texas. She evaluated the quest to use New Town (she calls it "New Community") designs to avoid the worst problems of urban sprawl.

Irvine has also been the subject of research where New Town principles were more of a backdrop than the focus. Maor (2011) showed how some New Town principles in a neighborhood in Irvine made for stronger place-attachments for residents compared with an otherwise similar neighborhood in the nearby city of Fountain Valley. Residents in the Irvine neighborhood of Woodbridge knew the name of their tract and recognized the edges of it whereas the residents of the tract in Fountain Valley did not even know their neighborhood had a name. Piggot (2009) explored the transformation of suburban political culture using Irvine as an example of a New Town development. He found that suburbanization has no necessary connection to political conservatism and with Irvine's close connection to a big university and adherence to the New Town ideals, the voters were less politically conservative than expected. The current study looks at another aspect of the City of Irvine - land use change over time in a master-planned community.

2.2. Urban Planning and The New Town Movement

The history of urban planning in the New World goes back a long time. "The Laws of the Indies" were a set of guidelines signed by King Phillip II of Spain in 1573 "to instruct Spanish Colonists on how to create and expand towns in Spanish America." These rules for a city planning process represented some of the first attempts at General Plans in America. The oldest

planned community being St Augustine, Florida which was laid out in 1603. (National Park Service).

In the late 1800s, Ebenezer Howard developed the Garden City Movement as an alternative to urban sprawl. Garden cities were planned, self-contained communities with a balance of residences, industry, and agriculture all surrounded by corridors of nature (D. Kane 1996). There would be small villages with schools, churches and shops, surrounding a bigger city center where government offices and industry were located. The New Towns movement of the early 1900s built upon this Garden City Movement. It is sometimes also called the New Communities movement.

The aims of the New Towns movement were to avoid the problems of big cities and those of rural small town through advanced planning. Those goals included 1) providing a sense of community identity, 2) preserving open space for nature, with trails for biking and walking, 3) promoting mass transit, 4) providing housing at a wide variety of social and economic levels and 5) planning for jobs to be nearby (Wakeman 2016). There was to be a mix of land uses to encourage interaction between different social, economic, age and racial groups, and to provide open space for recreation (Forsyth 2005). Unlike Ebenezer Howard's Garden Cities, New Town proponents wanted to bring back the dense city center to create a sense of community and place identity. These new communities would be planned as pedestrian-oriented neighborhoods that would encourage walking and mass transit (D. Kane 1996).

William Pereira was the architect who created the master plan for the entire Irvine Ranch which he finished in 1960. This was "potentially the largest new community in the United States" (Wilsey & Ham 1973, i-1). Pereira had a large, blank slate upon which to test these New Towns ideas for building convenient, healthful, efficient, and attractive communities. The City of

Irvine was built with many hallmarks of the New Town movement. For example, every housing tract has a park, every village has a school, and there are 54 miles of off-street bicycle trails (City of Irvine 2016b). Each village was given a distinct look by giving the residences a certain architectural style and by using a different set of trees, shrubs and flowering plants in the landscaping. Early plans also had mass transit corridors, but the mass transit was never built. The corridors remain should there be enough people for a mass transit system in the future.

A General Plan for a city is a master plan of all the elements that will make up the city. The General Plan for the City of Irvine contains sections for land-use, transportation, cultural resources, public facilities, conservation and open space, waste management and other elements. The City of Irvine describes the "Land Use Element" of their General Plan as:

> The Land Use Element seeks to protect and enhance the quality of life in the community. Land use policies determine how land is developed in the community, ranging from an office building or a single-family home, to the number of parks and open space areas in the City. Land Use policies also guide and resolve many land use issues and constraints to define the quality of life in the City. City planners today strive for a balance in land use with one-third in residential, one-third in non-residential and one-third of the land left in open space and recreation (City of Irvine 2015, 2).

There have been several comprehensive updates to the City's original General Plan since 1971. A city's General Plan needs to provide for safety, public facilities and infrastructure, parks and recreation, housing, education, business employment, health and medical, homeowners' associations, and cultural amenities. The overall land use planned for Irvine is one-third residential, one-third non-residential use and one-third open space or recreation. (City of Irvine 2016a).

2.3. Extracting Data from Old Maps

The use of GIS for historical research falls into two categories: using a GIS to build a historical/geographical database and using GIS as an aide in historical research (von Lunen 2013). When working on reconstructing the past, historical maps are sometimes the only source of certain pieces of information (Rumsey and Williams 2002). At the larger end of the scale, there many country-wide historical GIS (HGIS) databases being developed all over the world (Knowles and Hillier 2008). Smaller projects often deal with just one city or even just one section of a city. Rosen (2015) geocoded old Sanborn Fire Insurance maps to create a geocoder database of pre-1908 San Francisco. The GIS was necessary for georeferencing the old maps to a current base map and storing the address information for each location. Another study zoomed in on just one neighborhood: land parcels in four historical maps, from as far back as 1764, were digitized and compared to test the persistence of land use types by parcel in the Minorcan Quarter of St. Augustine, Florida. (Baldwin 2014).

Urban and planning historians do not use GIS very often (Hillier, 2010). A survey of 348 articles in the Journal of Urban History and the Journal of Planning history showed that only 47 had new maps and less than half of those had maps created by a GIS. This is unfortunate since GIS is quite useful for integrating different datasets that might otherwise be difficult to study together (Kemp 2009; Gregory 2014). It is not easy for human eyes to compare historical maps with digital maps and find patterns or detect differences. To enable the computer to do these tasks, the historical maps must be converted to digital data.

2.4. Building Historical Narratives

Historians use narratives to construct the story of a place and GIS can help to build that narrative. Bodenhamer (2010) points out that a location is not just a place for something to

happen but is a “significant product of and determinant of change.” The historical narrative of a place seeks to connect events and develop a meaningful story providing perspective to help readers understand that place. A GIS not only keeps track of what happened, where and when, but it can store attributes of each event which enables analysis of the connections between events and the effects of each attribute. The study of the regrading of the Denny neighborhood used GIS to explore and re-create the erasing of a large hill in the middle of Seattle, Washington in the early 1900s (Raymond 2011). Raymond used Sanborn insurance maps (historical maps), city engineering records, county assessor records and other data to create datasets. He made a blocks layer to use as a baseline and an historical buildings layer with attributes such as height, use, footprint, and year built so he could track these buildings over the years covered by the case study. Having all the buildings data in one geodatabase made it easy to select only those buildings for the year(s) of interest. Once they could view the data visually, they could see patterns that were not noticed before such as the relative proportion of space dedicated to a type of use. For example, before cars there were 27 structures in Seattle for “stables,” but by 1900 most were gone.

2.5. Using GIS to Track Land Use Changes

Many researchers have found geographical information systems useful for tracking land use changes over time. GIS has been used to trace types of development of Long Island City over a 59-year period (Mamer 2015). A point was digitized for every spot that contained a building in any of the five time periods, and the study then tracked shifting uses between cultural, industrial, residential and other categories. This data enabled tracking where industrialization grew and finding the trends for each use type. A project in Slovakia compared current data with digital layers prepared from four historic maps dating back to 1782. Thirteen land use types were

condensed into five for the project and then the maps were digitized. The purpose was to compare track and compare land use changes during three different political periods. They had to watch for features that disappeared over time or had their names changed during the 224 years (Kanianska et al. 2013).

Land use change studies using historic maps often must manually digitize the old map. In studying land use change along the coast of Devon, England, Comber et al (2016) digitized the survey maps from 1965 according to what different individual surveyors recorded. They used this data to track the impacts of different land management regimes by putting the data in a change matrix to quantify class-to-class land use changes. A group from Arizona State University analyzed old maps to see if the data supported a common historical narrative. For this study, the researchers made parcel-level digitizations of three old Sanborn maps covering almost 50 years to study the growth patterns of early Phoenix, Arizona (K. Kane et al. 2014).

Many studies have used GIS to study land use changes and many have studied the master-planned communities of the 1960s and 1970s. This paper, for the first time, brings GIS, tracking land use changes and the study of a master-planned community all together in one study.

Chapter 3 Methodology

The purpose of this study is to see how closely Irvine's original land use plan was followed. A hard-copy of the 1973 Irvine Ranch General Plan map served as the baseline for the original land use plan, and a 2017 City of Irvine parcel shapefile served as the current land use data. First, this chapter discusses how and why the 1973 map was chosen as the baseline for historical data. Then it describes processing the data layers. The chapter then discusses the land use codes used for each period and the process of selecting compatible codes for comparison. Finally, the chapter describes the process by which historical and current land use codes were compared by location.

3.1. Research Design

This study assesses land use change by comparing spatial data in City of Irvine's General Plan in 1973 with spatial data from the same locations in 2017. The land use map created for the Irvine Ranch in 1973 was imported as a PDF into ArcMap 10.5 and converted to polygons that could be compared with 2017 City of Irvine land use data to see if the land use codes had changed over time.

3.2. Data Sources

This study compares current land use data against the intended land use for Irvine from the early days of its cityhood. Current land use data exists as parcel polygons created and housed in the City of Irvine's GIS. Historical data of the city's early General Plan did not exist as spatial data within a GIS. A historical map needed to be input into a GIS. The first step in this process was to choose the best historical map for consumption by a GIS, described in section 3.2.1. The process for inputting the chosen historical data into a GIS is described in section 3.2.2. The early

land use data employed are described in section 3.2.3. Finally, the process of consolidating land use codes from each period and assigning appropriate code to each polygon, both historical and current, is described in section 3.2.4. The last section, 3.2.5, discusses how the land use codes were matched between the two years.

3.2.1. Choosing the Historical Irvine General Plan Map

This section describes the process for choosing the 1973 General Plan map as the baseline historical data for this project, as opposed to other maps from that time. Several historical maps of the General Plan exist. The Raymond Watson collection at UCI (Watson 1964) contains a map in the booklet "Irvine General Plan 1970" (Figure 4) but it has no colors for the different land use codes and does not have as much detail as the 1973 map.

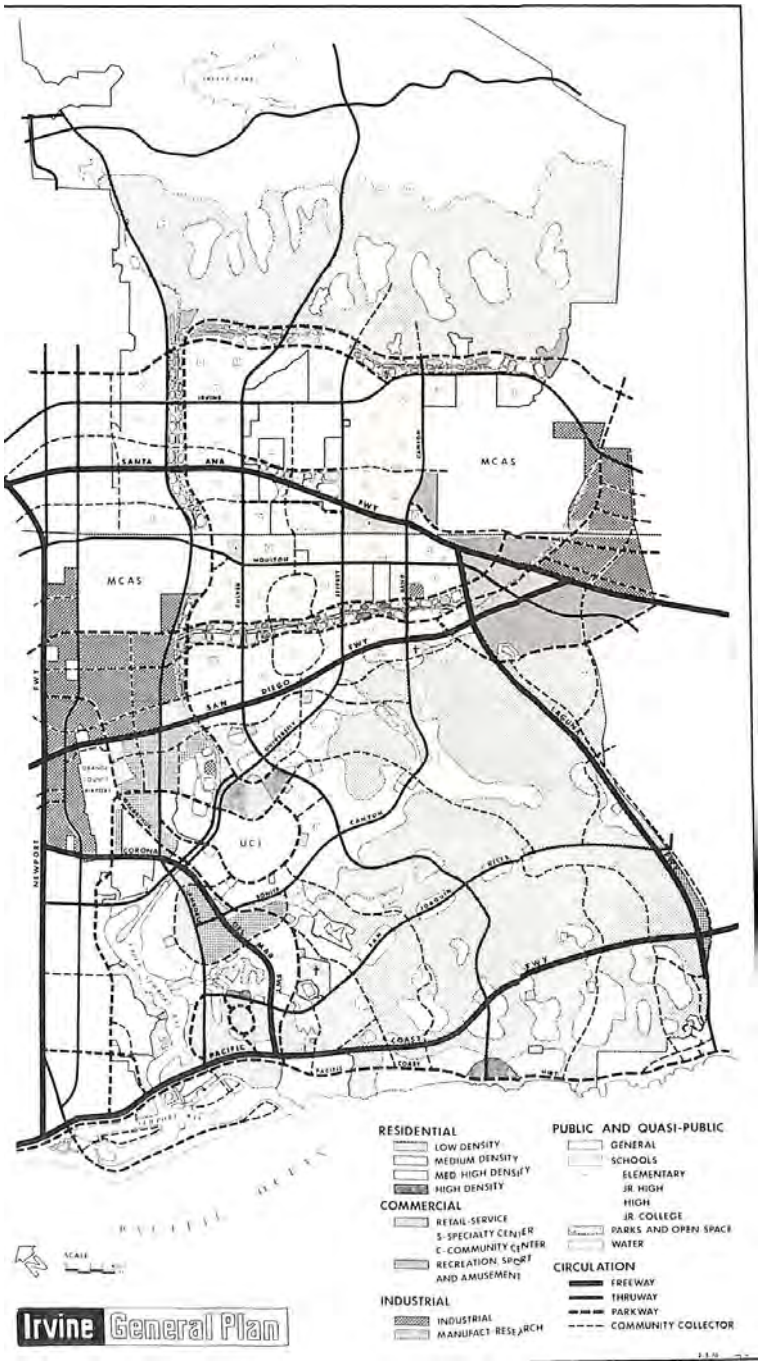

Figure 4 Irvine General Plan of 1970 From the Raymond Watson Collection

The Irvine Historical Society has two large wall maps of the Irvine Ranch. Each map is s about six feet tall and, therefore, difficult to work with (Figure 5). They are so large that one-inch on the map represents 2,000-feet on the ground. One map is The Irvine Company's General Plan in 1973, and the other is an aerial photograph with major features labeled. The aerial photograph is dated 1998. They are hanging side by side in the museum so it is easy for visitors to compare them.

The Irvine Company very kindly provided seven PDF images of General Plan land use maps covering a range of dates. One map is undated but probably from before 1970 judging from the contents of the map (Figure 6). Note that this map does depict the environmental corridors which were a big deal to The Irvine Company's Richard Reese who said, in 1970, "Just as Paris is known by its boulevards and Venice by its canals, the City of Irvine will be known by its environmental corridors (Irvine World News 1970, 2)." There was to be one North-South environmental corridor and one East-West environmental corridor. This map has a separate icon in the legend for "Environmental Corridor." In the historical map chosen for this study, the environmental corridors are still shown on the map but no longer listed in the legend. Another Irvine Company image is a 1973 land use map for the entire Irvine Ranch. The other five maps provided by the Irvine Company are much newer, spanning 1990 to 2015.

The City of Irvine's original filing of a General Plan in 1973 with the County of Orange contains three different land use plans (Wilsey and Ham1973). With the main roads already in place, the University of California at Irvine already established, and several housing tracts built by 1970, the new city's General Plan had to resemble the General Plan developed by The Irvine Company. All three options in the original filing were based on the Irvine Company's General Plan. The Moderate Land Use Plan (Option 1) describes a total population in the city of 199,302

with an additional 74,316 residents in its sphere of influence. The Maximum Land Use Plan (Option 2) would have a city population of 221,895 and a sphere of influence population of 166,891. The third option, the Minimum Land Use Plan (Option 3) preserves 63% of the land in open space or agriculture and has the fewest people with a final population of 176,801 in the city and only 367 in the sphere of influence. Also of note, these three options cover the entire Irvine Ranch which is nearly 100,000 acres yet the City of Irvine itself was only 28.3 square miles. The plan they finally adopted had dropped the coastal section below Bonita Canyon road but still included all the land southeast to El Toro and north east into the foothills.

The City Council did not approve a land use plan until December of 1977, six years after incorporation. They chose none of the above options but, instead, a compromise between Options 1 and 3 where the total final population would be 214,000 (Figure 2) by 2010 (City of Irvine 1978). This official General Plan for land use has many similarities with the June 1973 General Plan by The Irvine Company (Figure 7). The main differences in the city's plan are that some non-major roads take different routes and the north-south environmental corridor is gone.

The Irvine Company's General Plan map from 1973 (Figure 7) was used as the historical starting point for several reasons. The main reason is because this plan was William Pereira's original vision for the New Town master planned community on the Irvine Ranch. Another reason is this map is dated. Many of these early maps had no dates on them, but this one is dated "June 1973" in the lower right corner. Also, the level of detail in the chosen map is much finer than the others which, along with the color-coding of the map according to land use, made this map the most accurate available for the early 1970s. This is not one of the maps that the City of Irvine files with the County of Orange in 1973 but the basis upon which each option was built.

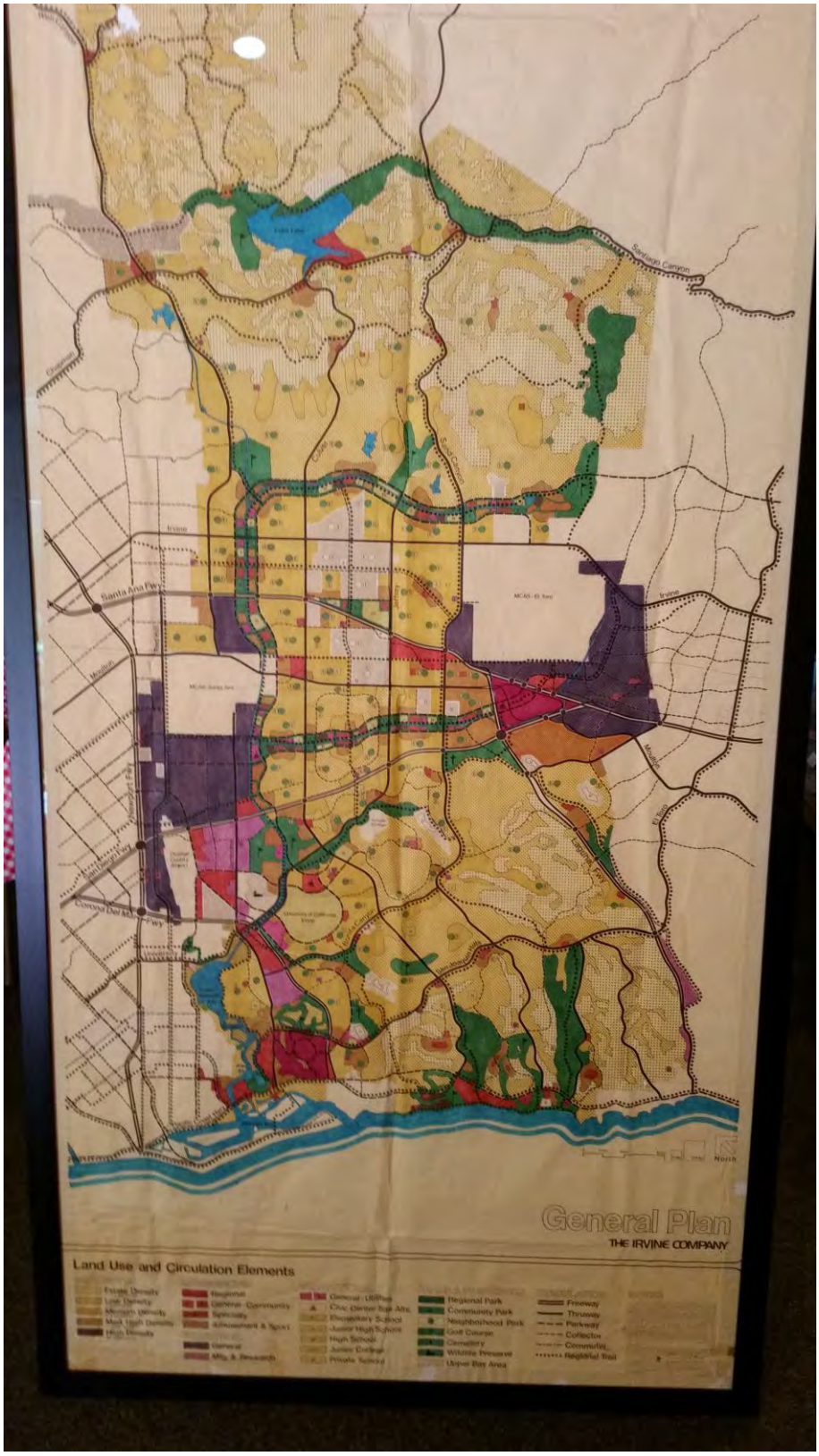

Figure 5 Six-foot-tall 1973 General Plan Map

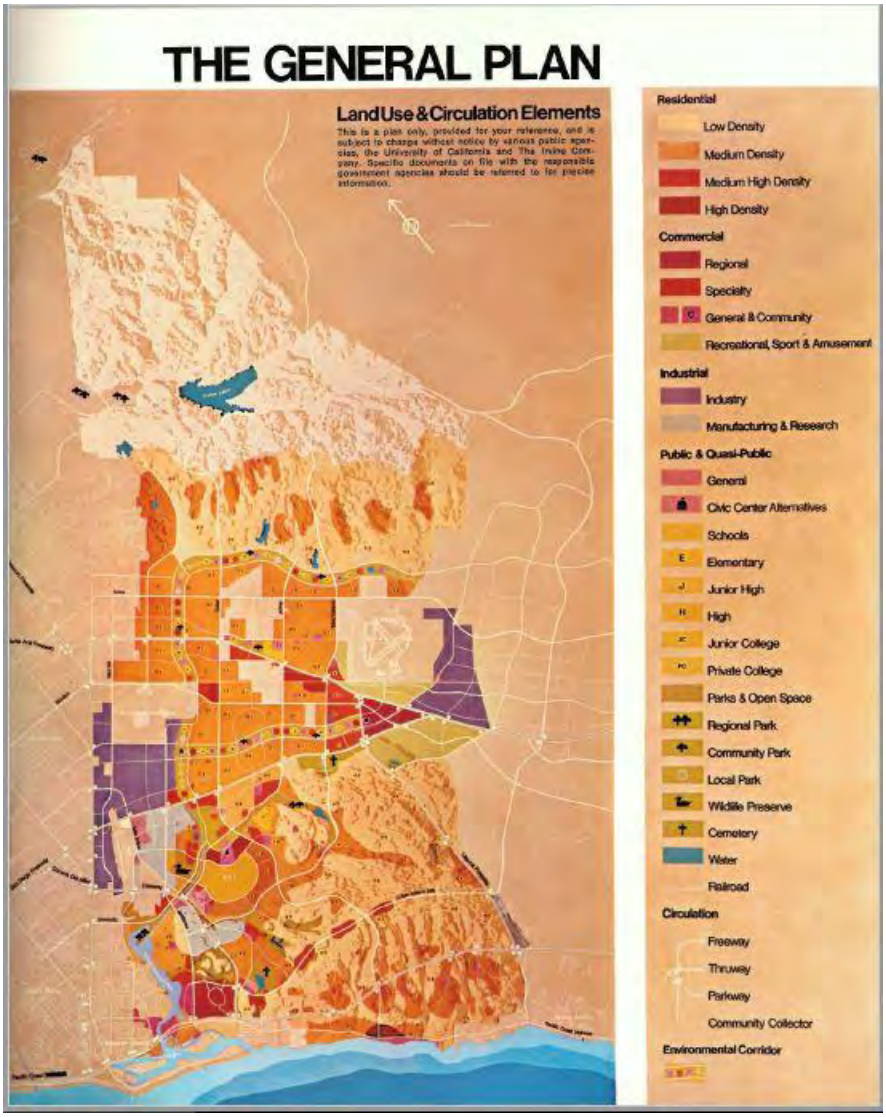

Figure 6 Pre-1970 General Plan Map of Land Use

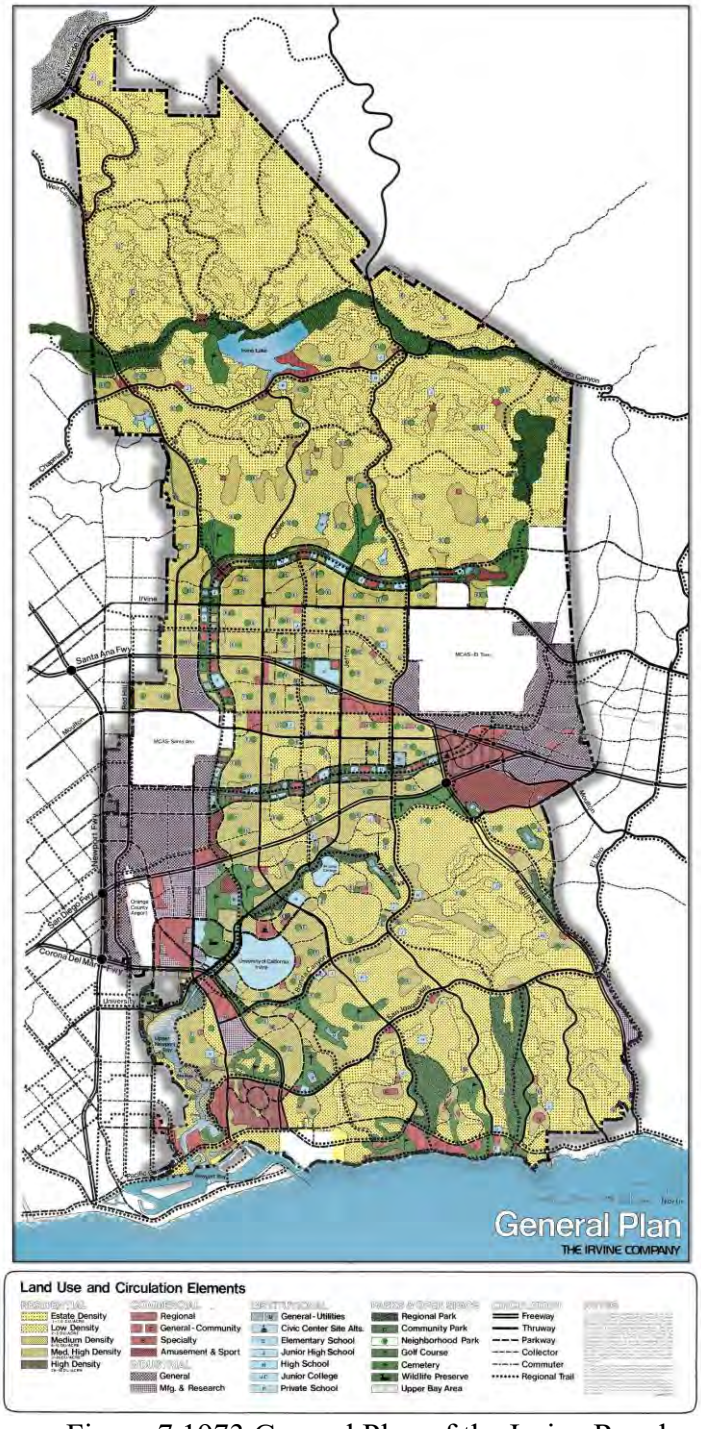

Figure 7 1973 General Plan of the Irvine Ranch

3.2.2. Importing the 1973 Map Into a GIS

The 1973 image from the Irvine Company needed many several steps to be ready for analysis. The PDF image was converted to a TIFF format because ArcMap can display a PDF but not extract data from it. The TIFF was then added using the same projection as the ESRI base map, Lambert_Conformal_Conic and NAD_1983_StatePlane_California_VI_FIPS_0406_Feet.

The 1973 map image was then georeferenced to match the base map. First, the scale had to be adjusted to fit the city's outline on the base map and the image had to be tilted. When shown by itself, the Irvine Ranch is usually depicted with the foothills in the north east at the top of the page. The Irvine Ranch sits in the map of California depicted at an angle. This meant the image needed to be rotated and shifted until the streets on the 1973 map lined up with those on the base map. Several ground control points were chosen at street intersections for the rubber sheeting process. Freeways were not used as control points since they have widened considerably since 1973. Finally, the image was rectified and the georeferencing saved. Georeferencing was carried out at a scale of 1:125,000. The Root Square Mean Error was 35.

3.2.3. Land Use Classifications in the 1970s

The Land Use Element was the first part of the new city to be detailed in the General Plan that the City of Irvine filed with the county. The three land use plan options described in section 3.2.1 all have the same land use codes. These are the same as in the Irvine Company's 1973 map (Figure 8) but the Irvine Company map has additional codes for Village Commercial, Agriculture, UCI, Nature Center, Wildlife Habitat and Airport.

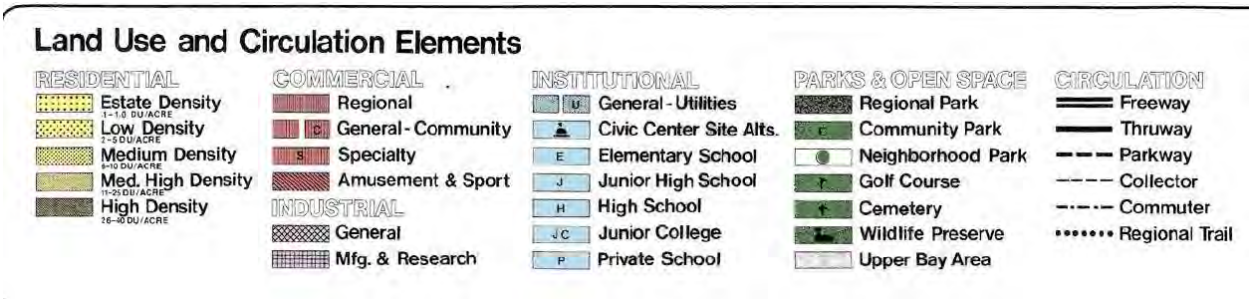

Figure 8 Land Use Classifications from the Irvine Company's 1973 Map

3.2.4. Land Use Codes in 2017

The parcel shapefile from the City of Irvine's GIS department contained 61,773 records. It does not contain cadastral data nor zoning data, but records how each parcel of land is being used as of February 4, 2017. The land use attribute is titled "Feature" and uses four-digit codes to indicate a land use category. The attribute table includes tract numbers and planning areas and, importantly, Shape_area and Shape_length of each parcel.

The City of Irvine's current Land Use Element has 71 different land use codes. The codes are arranged by categories such as Open Space, Residential, Institutional, and Public Services. There are two odd categories in the 2017 attributes, Military and Agriculture. There were two military bases on land that once belonged to the Irvine Ranch but there were no military bases inside the City of Irvine. The current land-use map now has a category of "Military" but there is a high school on that lot. Why is it coded military and not educational? The other oddity is the agriculture code. As late as 1960 the Irvine Ranch had over 4,000 acres in Oranges and over 7500 acres in grains (Cleland 1966). Thus, why did the 1973 Irvine Company map not have any category for farming or agriculture? The land that is now coded "Agriculture" is on the old El Toro Marine base.

3.2.5. Matching 1973 and 2017 Land Use Classifications

Land use classification schemes used by the Irvine Company in the 1973 General Plan map and those used in the 2017 parcel data have some slight differences. Classification changes between 1973 and 2017 are detailed in Table 1. The land-use category with the most changes since 1973 is the Parks & Open Space sector. All the park categories from 1973 now fall under Recreation. There is a new category of "Great Park" for the park being built on part of the old Marine Corps Air Station El Toro base. The old Wildlife Preserve has a new code Preservation. The old Upper Bay Area is now under Water Bodies. The 1973 category of Cemetery is gone because there has never been a cemetery in the City of Irvine. The category may come back as the city council has recently approved a veterans' cemetery near the old El Toro Marine base (City of Irvine 2017a). "Recreation, Sport and Amusement" is under "Commercial" because this category is for money-making recreation such as amusement parks and miniature golf courses. The Irvine Business Complex is under the main category of Industrial because "typical uses are professional/medical offices, industrial manufacturing, research and development, support service retail, restaurants, multifamily housing and hotel/motels (City of Irvine 2015, 7).

Table 1 Land Use Codes: Corresponding Nomenclature Between 1973 and 2017

	1973 Classifications	**Codes**	**2017 Classifications**
Residential			
	Estate	2100	Estate
	Low Density	2200	Low Density
	Medium Density	2300	Medium Density
	Medium High Density	2400	Med High Density
	High Density	2500	High Density
Commercial			
	Regional	4100	Commercial
	General and Community	4100	Commercial
	Specialty	4100	Commercial
	Recreation, Sport, Amuse.	4100	Commercial
Industrial			

	General	5100	Industrial
	Manufacturing & Research	5100	Industrial
	n/a	5200	Irvine Business Complex
Institutional			
	General & Utilities	5400	Institutional
	Civic Center Site Alternatives	5400	Institutional
	Elementary School	6100	Educational
	Junior High School	6100	Educational
	High School	6100	Educational
	Junior College	6100	Educational
	Private College	6100	Educational
Open Space			
	Regional Park	1510	Recreation
	Community Park	1510	Recreation
	Neighborhood Park	1510	Recreation
	Golf Course	n/a	n/a
	Wildlife Preserve	1300	Preservation
	Cemetery	n/a	n/a
Other	n/a	Other	Agriculture
	n/a		Landfill
	n/a		Military

The Residential classifications are basically unchanged. Both years under study had five codes for residential density. The only difference is in the definitions. In the 1973 codes, the next highest density started where the previous one left off. In 2017, all residential classifications begin at zero dwelling units per acre (Table 2). For example, Medium Density in 1973 was for at least six but no more than 10 dwelling units per acre whereas in 2017 Medium Density means any number from 0 up to and including 10 dwelling units per acre. Ground truthing a few housing tracts shows that, at least for the area under study, the original 1973 residential density definitions were followed.

Table 2 Comparison of Residential Land Use Codes

	1973 units per acre	**2017 units per acre**
Estate Density	0.1 to 1.0	0 to 1
Low Density	2 to 5	0 to 5
Medium Density	6 to 10	0 to 10
Med-High Density	11 to 25	0 to 25
High Density	26 to 40	0 to 40

Many of the records in the 2017 parcels layer were recoded. First, the land use codes used in 2017 were consolidated from 71 into 16 codes. The reason for consolidating all but the residential codes, is to avoid tracking minor changes such as changing a school from Elementary to Middle School. Also, most of the categories changed and expanded since 1973. Consolidating the seventy-one codes for 2017 enabled them to be more effectively matched with the twelve 1973 land use codes. This study is looking for changes between categories, not changes within a category, except for residential density. Therefore, all natural open spaces such as water channels, marshes, basins and wildlife preserves were coded 1300 for Open Space. The various levels of parks, for example community parks and neighborhood parks, became 1510 for Parks. The only residential categories to be combined were those for high-density residential. Apartments and condominiums were put into 2500, the High-Density Residential code. All commercial and industrial codes were consolidated into 4100 for “Commercial” and 5000 for Industrial, except for a new category 5200 for IBC Industrial, which puts residential units and industrial buildings together. Educational parcels from grade school to university level to administration were all combined into code 6000 for Educational while all other institutions

became code 5400. The final group of land use codes, freeways, toll roads, easements, are now code 8000 for this study. Land use codes with no parcels within the 1971 city limit were omitted.

The second recoding involved roads and landscaping. These were recoded because there were no minor roads on the 1973 map and to get meaningful pairings with 2017 there should be no minor roads inside housing tracts in the current year's data. All the different types of roads became 3100 for Roads. Roads inside a housing tract or inside an office park were recoded to match the surrounding parcels. Landscaping strips were the third group to be recoded to match the parcels they were attached to. For example, the landscaping surrounding a high-density housing tract should be coded as high-density residential.

3.3. Data Processing

Three layers of data were used in the processing, the 1973 Irvine Ranch map image from the Irvine Company, a parcel shapefile for 2017, and a 1971 city limit shapefile, the latter two from the City of Irvine GIS Department. Section 3.3.1 describes extracting land use codes from the 1973 polygons layer into points inside each 2017 parcel. Checking the geometry of the 2017 file and using the historical map to clip this data to the city's 1971 boundary is described in 3.3.2.

3.3.1. Extracting Data from Historical Map

The next step was to extract land-use codes from the 1973 map. There were 61,773 parcels in the City of Irvine in 2017 but in 1973, there were probably only a few thousand parcels. It is assumed that none of the 1973 parcels were joined or combined between 1973 and 2017. Since the city was growing and developing, the parcels of 1973 either kept the same boundaries or were divided into smaller parcels over time. To verify this assumption, the 2017 parcel layer's outlines were thickened and the polygons were made hollow. A visual check of

each of the 2017 parcels through to the 1973 layer was done to verify there were no parcels from 2017 which had two different colors in 1973, and therefore two proscribed land uses.

Two fields were added to the 2017 map's attribute table. The fields were named "Longitude" and "Latitude" and were of the type Double. The Calculate Geometry tool in the Data Management toolbox was used to calculate the X and Y coordinates of the centroid on each parcel. This tool added the X, Y coordinates of each parcel's centroid to the 2017 map's attribute table. This table was then exported to a new table and added to the 2017 map. Display XY Data was used to make a new point layer of parcel centroids. The Extract Values to Points tool requires the source layer to be in raster format so a new raster layer was made from the 1973 layer with a cell size of 150 feet. The Extract Values to Points tool from the Spatial Analyst toolbox was used to bring a land-use value from the 1973 map raster data into the 2017 map's attribute table for each parcel's centroid. The Extract Values to Points tool took a long time to run, but a new field named RasterValu was added containing 1973 land use codes.

Unfortunately, the quality of the 1973 map was not so useful at the scale necessary (Figure 9). When Extract Values to Points was run there were 257 different values for land use with 6595 records having a RasterValu of "255." Only around 25 different values of land use codes were expected.

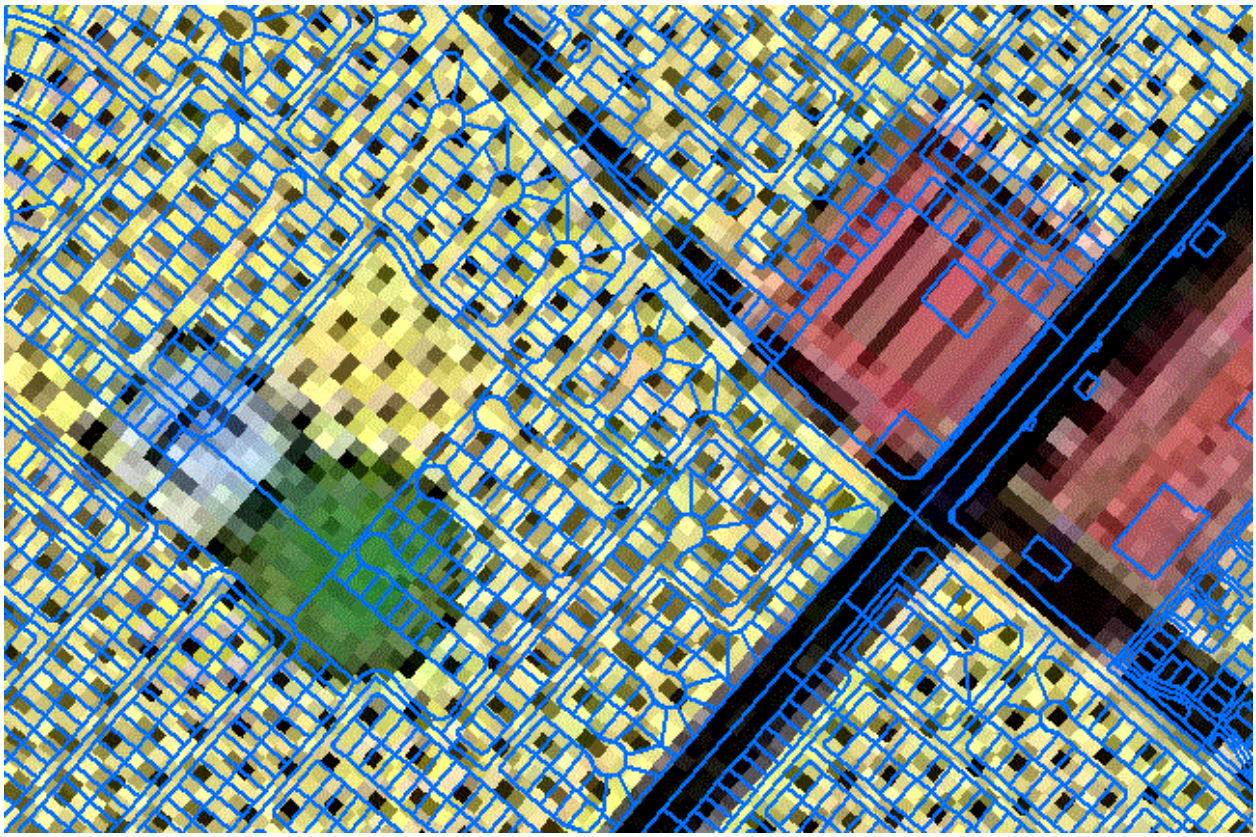

Figure 9 Inconsistent Coloring of Same Code Parcels

The problem is the quality of the graphics. The 1973 map was not designed to be used at such a large scale by something as exact as a computer. When enlarged to the scale where individual house parcels are visible, the graphics were such that ten houses in a row could be assigned ten different land use codes even though they were all the same (Figure 10). In the picture below, every visible parcel (outlined in blue) of this housing tract should have the same land use code. However, GIS will pick up one value for brown, one value for dark brown, one

value for each of the greens and so on. This picture alone would generate 15-20 different values based on color when there should only be one value.

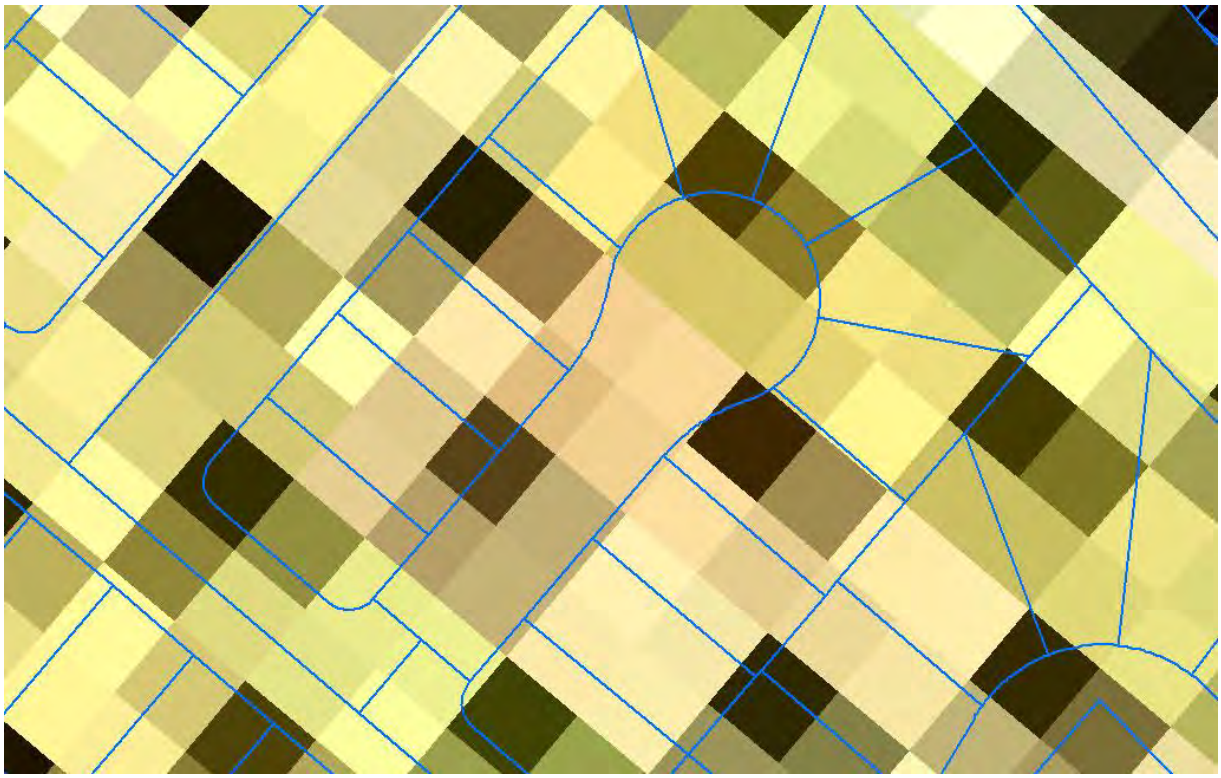

Figure 10 Fine Detail of the Inconsistent Coloring.

Round two with the 1973 map was to manually digitize polygons based on the land use colors in the map. A new vector layer was created using Auto Complete Polygon in Create Features. Making polygons following the sections of different color patterns in the source map made it possible to make a layer where each polygon contained a single, solid color. This enables the Extract Value to Point tool to pick up the same value for every point over the same polygon and, therefore, the same land use section. The polygons were digitized at a scale of 1:8000 and only parts of the map within the 1971 city limit were digitized. Initially, the main roads were not digitized but polygons for roads were added later. This led to many slivers and other topology

errors. Having the first set of polygons created by Auto Complete made inserting the roads polygons more error prone. Check Geometry and Fix Geometry were run on the new polygon layer. A topology layer was generated to enable fixing of errors such as slivers, overlaps, gaps or polygons that self-intersected.

Schools were given special treatment. Schools on the 1973 plan, represented by a green circle and a letter in a blue box, were randomly placed within the housing tracts (Figure 11).

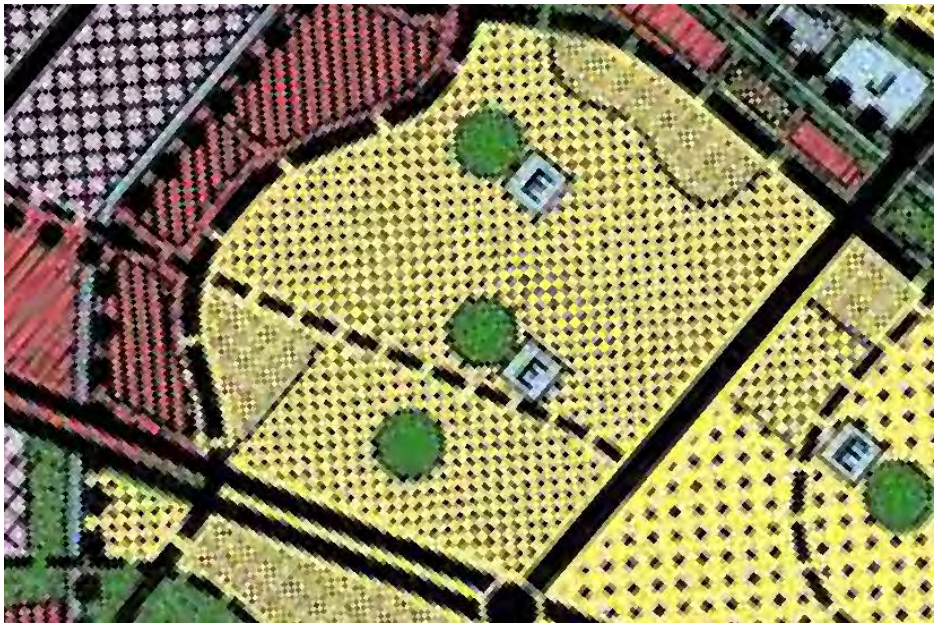

Figure 11 Green Circles for Schools in the 1973 Map

When making the polygons layer, the polygons for the schools were created in the same location where schools existed in 2017 (Figure 12). The focus of this study is how many acres of land is being used for education and not if the proposed schools were built in the exact locations as on the General Plan. At least 2 of the proposed schools were never built.

Figure 12 Green Polygons in Actual 2017 School Locations

After all the parcels were drawn, the attribute field for land use in 1973, "LU1973," was manually populated based on a visual comparison of the graphics in the parcel with the legend at the bottom of the original map. Once all the 1973 parcels had land use codes, unique colors were assigned to each code. To check the accuracy of coding by hand, one code at a time was made colorless to verify that all sections of the original image showed through with the same pattern. Figure 13 illustrates how code 4100 was made hollow to verify that every parcel for 4100 has the same 1973 graphic. A new raster was then created for use by the Extract Values to Point tool.

Figure 13 Verifying Coding of 1973 Polygons

The final product of digitizing the 1973 Land Use General Plan from the Irvine Company is shown in Figure 14. Only those areas within the 1971 City of Irvine boundary were included. Each different land use code has a different color. The large Irvine Business Complex stands out in yellow in the upper left of the map. The University of California at Irvine is clearly visible as a large section of cobalt blue in the lower left. The large housing tracts of Northwood, Woodbridge, and Turtle Rock are represented by ovals aligned down the center of the map from the north east down to the south west. The one remaining environmental corridor is visible running through the center of the city connecting the two business complexes, the regional commercial center, and the residential areas. The business complex opposite the Irvine Business Complex is called the Irvine Spectrum. This complex and the Spectrum Entertainment Center are not part of the city yet in 1973 but they can be seen on the gray base map by following the environmental corridor to the south east where the freeways meet. The city planners wanted the main traffic arteries running top to bottom and left to right in this new city.

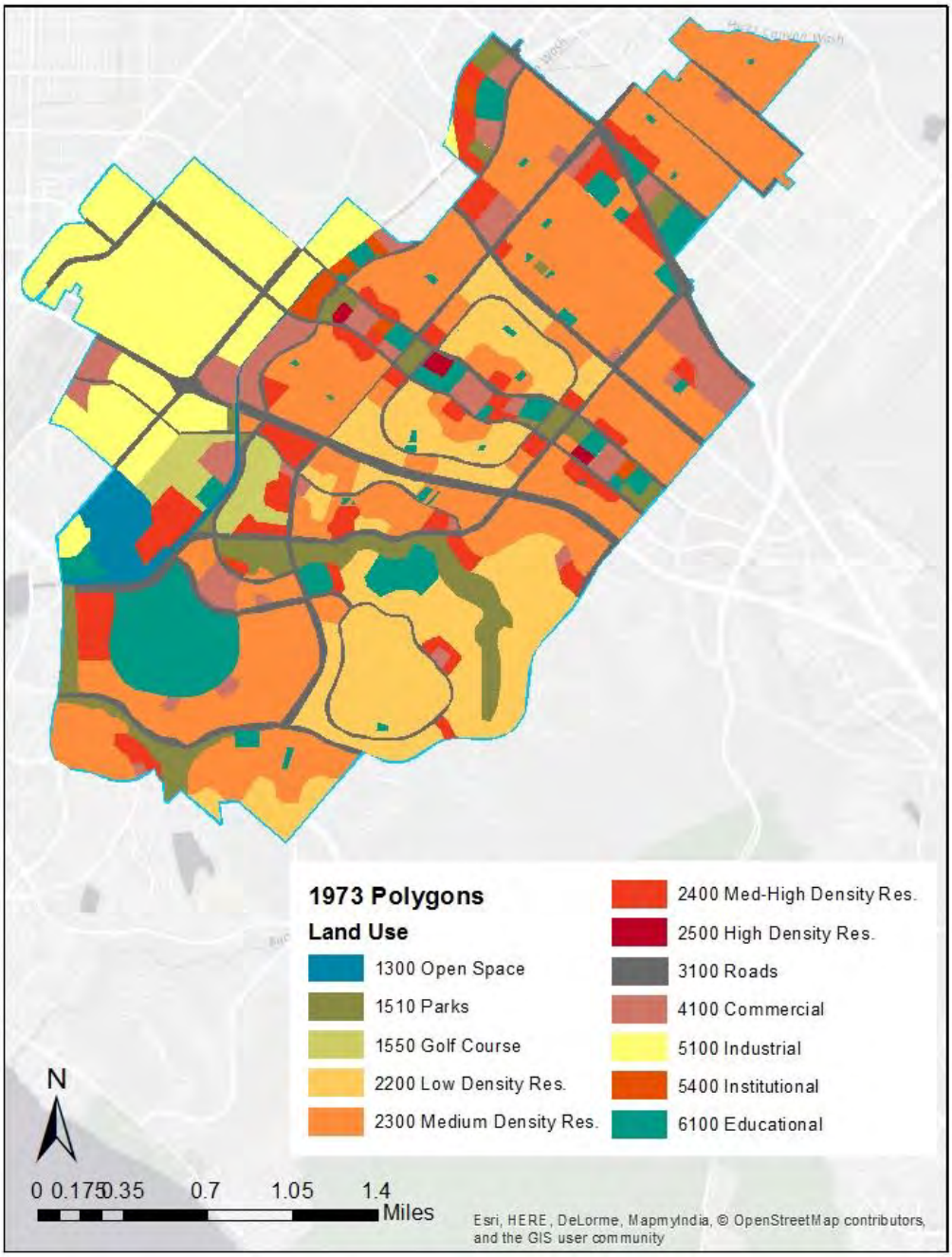

Figure 14 Digitized Version of 1973 General Plan Land Use

For the second extraction attempt, the Feature to Point tool was used on the 2017 database. The Feature to Point tool uses the center of gravity of a polygon to create a point for that polygon. The option of "Inside" was checked to keep the points inside their polygons. A new feature class of points was created for the 2017 database. Extract Value to Points was used to pull values from the 1973 polygon raster layer into the new points layer. This time there were only 13 different land use codes. Code 0 was assigned to all parcels that did not get a 1973 value since they were outside the 1971 city limit and therefore had no polygons created. The points layer, with LU1973 and LU2017, was joined with the 2017 polygon layer to join the land use data with the parcel area data. Field Calculator was used to move the 1973 values into a column in the 2017 layer.

3.3.2. Preparing the 2017 layers

Much work needed to be done on the 2017 parcels layer but not the city limit layer. The GIS department at the City of Irvine supplied a shapefile of 61,773 parcels with a land use code for each parcel. The city's shapefile also contained the area for each parcel. The 1971 shapefile for the city limits was imported and made hollow with a thicker outline. The 2017 parcel file was imported and checked for errors with the Check Geometry tool. Several things needed repaired such as slivers and parcels with the error "Must not self-intersect." The Repair Geometry tool corrected the "Must not self-intersect" errors and all but the tiniest slivers were manually repaired. The current land use codes were then copied to another column for back up and future reference. After the points values were added via a join, the join was undone. Next, the size of the 2017 layer was reduced to contain only parcels inside the 1971 layer, using Select by Attribute and selecting for LU1973 greater than 0. This means that only those parcels with a value extracted from the 1973 polygons layer remained in the dataset. The resulting 2017 dataset

had 32,773 records. The Select by Location option did not work, because when the city boundary coincided with the edges of a row of parcels, ArcMap appeared to randomly assign parcels inside or outside the study area along that line.

3.3.3. Finding Land Use Changes

To find where land use differed between the two years, the layer that now had both the land use code for 1973 (LU1973) and for 2017 (LU2017) was exported to Excel. This table also contained area, in feet, for each parcel which was used to measure the size of land use change. In Excel, the pivot table tool was used to tally pairings between codes in the 2017 columns and for 1973 in rows. Land use in 1973 is on the x-axis while land use in 2017 is on the y-axis. Raw results tabulated by square feet (Figure 15) and (Figure 16). Some pairings did not occur so the cell is blank. For example, there were no parcels with a value of 1510 in 1973 that changed to 2100 in 2017.

Sum of SHAPE_area	2017 Codes							
1973 codes	1100	1300	1510	1550	2100	2200	2300	2400
1300		10,187,188.4159						
1510		1,913,530.0367	10,766,876.3812	7,985,114.7110		171,634.3918	535,974.8904	296,189.9190
1550	44,454.8125	8,452,241.9515	41,400.5000	6,262,527.8520				
2200		32,241,106.8675	6,736,626.5341	2,934,372.2370	1,086,641.2772	38,343,784.5954	4,251,515.9092	251,610.8425
2300	342,144.7867	16,265,894.6571	16,103,079.6746	6,448,264.4392	362.5607	84,721,219.2258	23,320,759.7349	4,232,239.7562
2400		4,994,720.1797	2,771,863.7842		7,042.0000	1,693,081.7284	2,830,286.7956	923,996.3560
2500		421,326.3125						
3100		3,398,612.3236	2,260,609.8990	9,557.0411		4,823,666.6752	1,265,913.4282	310,710.1097
4100		2,101,877.4512	2,837,491.3267	1,874,459.6017		728,829.3576	193,780.0553	522,094.7867
5100		624,698.7385						
5400		947,951.8147	34,885.5201				158,235.0815	390,883.1577
6100		529,231.8210	524,451.4769			1,954,180.3389	737,575.2422	394,661.6092
Grand Total	**386,599.5992**	**82,078,380.5699**	**42,077,285.0970**	**25,514,295.8821**	**1,094,045.8380**	**132,436,396.3130**	**33,294,041.1373**	**7,322,386.5370**

Figure 15 Pivot Table Results in Square Feet (Page 1)

2500	3100	4100	5100	5200	5400	6100	8000	Grand Total
	62,781.9861					2,809,242.1667		13,059,213
3,123,512.0618	1,613,082.0246	1,878,851.8251	202,352.1464		1,204,135.0315	595,335.3792	382,288.2745	30,668,877
601,471.1092	336,199.6665	168,242.8270	803,848.0943		1,912,616.0474			18,623,003
23,620,827.2660	6,816,135.6824				621,766.7685	471,774.0625	2,571,705.0237	119,947,867
27,319,375.9903	11,362,883.7407	8,353,101.3587			3,112,067.4821	35,290,674.5143	8,929,738.8847	245,801,807
15,552,647.9876	3,456,944.9367	4,431,115.8460			764,530.1140	4,622,872.6601	2,690,428.9743	44,739,531
774,016.9666	89,694.2141	245,534.4375				186,172.1875	193,161.3125	1,909,905
4,673,110.2291	22,052,412.5480	1,783,695.5576	2,089,171.9892		237,967.2081	965,377.1739	15,915,666.9290	59,786,471
9,696,401.8565	3,002,089.5627	11,529,182.5644	4,646,242.9327		2,435,205.9181	928,594.5096	4,282,280.4706	44,778,530
	7,424,400.7906	2,825,916.4856	86,733,441.2222	3,950,786.5265	847,294.4300	101,609.6008	2,682,170.9898	105,190,319
443,534.1640	287,432.4758	1,043,768.5014			674,955.3016		434,004.8013	4,415,651
5,286,714.2335	2,931,621.2376	2,741,299.2052			4,151,950.6616	43,898,203.4441	1,084,314.4592	64,234,204
91,091,611.8646	**59,435,678.8657**	**35,000,708.6083**	**94,475,056.3847**	**3,950,786.5265**	**15,962,488.9628**	**89,869,855.6986**	**39,165,760.1198**	**753,155,378**

Figure 16 Pivot Table Results in Square Feet (Page 2)

The pivot table results show pairings between land use codes from 1973 and from 2017. For example, the pairing between code 1300 in 1973 and 1300 in 2017 was over 10 million square feet. This indicates that over 10 million square feet did NOT change land use codes between the two years. Another example explains how the results look if there was a change. Looking where the 1973 code of 1510 pairs up with the 2017 code of 1300 indicates there were 1,913,520.0367 square feet that changed between 1973 and 2017. The blank cells in the pivot table indicate that there were no parcels with the pairing of those two codes. All cell values were divided by 43560 to convert the values from feet to acres.

Chapter 4 Results

Comparing land use codes between the 1973 General Plan and the 2017 land use database reveals several interesting developments. Overall, there were more acres of changed codes than acres that remained the same code. The hypothesis that residential density would only increase over time did not prove true. Several pairs of land use change codes were selected for a more in-depth study. Of special interest were the pairs involving housing. The most changes by acreage were in the housing sector. There were also new codes added for the Irvine Business Complex allowing residences into the business park. These three new IBC land use codes were tracked in this study by the "IBC" code where the older parts of the business complex were tracked by the "Industrial" code.

4.1. The Big Picture

Although some of the land use change pairs between 1973 and 2017 affected no acres, a great many change pairs did involve significant acreage. The land use codes related to housing had the most changes by acreage with the change pair of Medium Density Residential to Low Density Residential reaching almost 2000 acres. The 1973 land use category with the fewest acres of change was High Density Residential, while the 1973 land use category with the fewest acres of change by percentage of total acres in a land use category was Institutional at 17.5% changed.

The direction of some of the changes was surprising. Lower density residential would be expected to be changed to higher density residential over the decades as more people move to Irvine or find jobs in Irvine and wish to live in the city. However, the biggest change involving

the residential land used codes was the huge number of acres changing from Medium Density Residential to Low Density Residential.

The data is presented in a table in Appendix B showing land use change pairs in acres. Below the actual acres are percentages of the1973 land use area changed.

4.1.1. Largest Areas of Change and of No Change

About two-thirds of the acreage in this study changed land-use codes between 1973 and 2017 (Figure 17). This was a much greater amount of change than was expected. The expectation was for some of each residential category to move to a denser category. Little change was expected in any of the non-residential categories. However, of the 17,290 acres in the 1973 General Plan, 11,425 acres had changed land-use codes and 5,864 did not. The biggest single parcel to be re-coded (shown in yellow) was on the University of California at Irvine campus where land previously planned as Medium Density Residential was re-coded to Educational. What exists on the land in 2017 is student housing, so this is a matter of reclassifying the land use and not of changing how the land was to be used.

Another interesting occurrence in Figure 17 is the loss of land along the southwest border of the city. The land inside the blue 1971 city limit line, but not colored green or black, was lost in two resolutions. The Southern Boundary Re-Organization resolution in 1997, (City of Irvine 1997), traded many parcels back and forth between Irvine and the neighboring city to the south, Newport Beach. The net loss to the City of Irvine was 61 acres. In 1998, the Bonita Canyon Detachment (City of Irvine 1998) caused the city another net loss of 460 acres. These resolutions re-aligned the boundary between the cities of Irvine and Newport Beach along the San Joaquin Hills Transportation Corridor which was built in 1996.

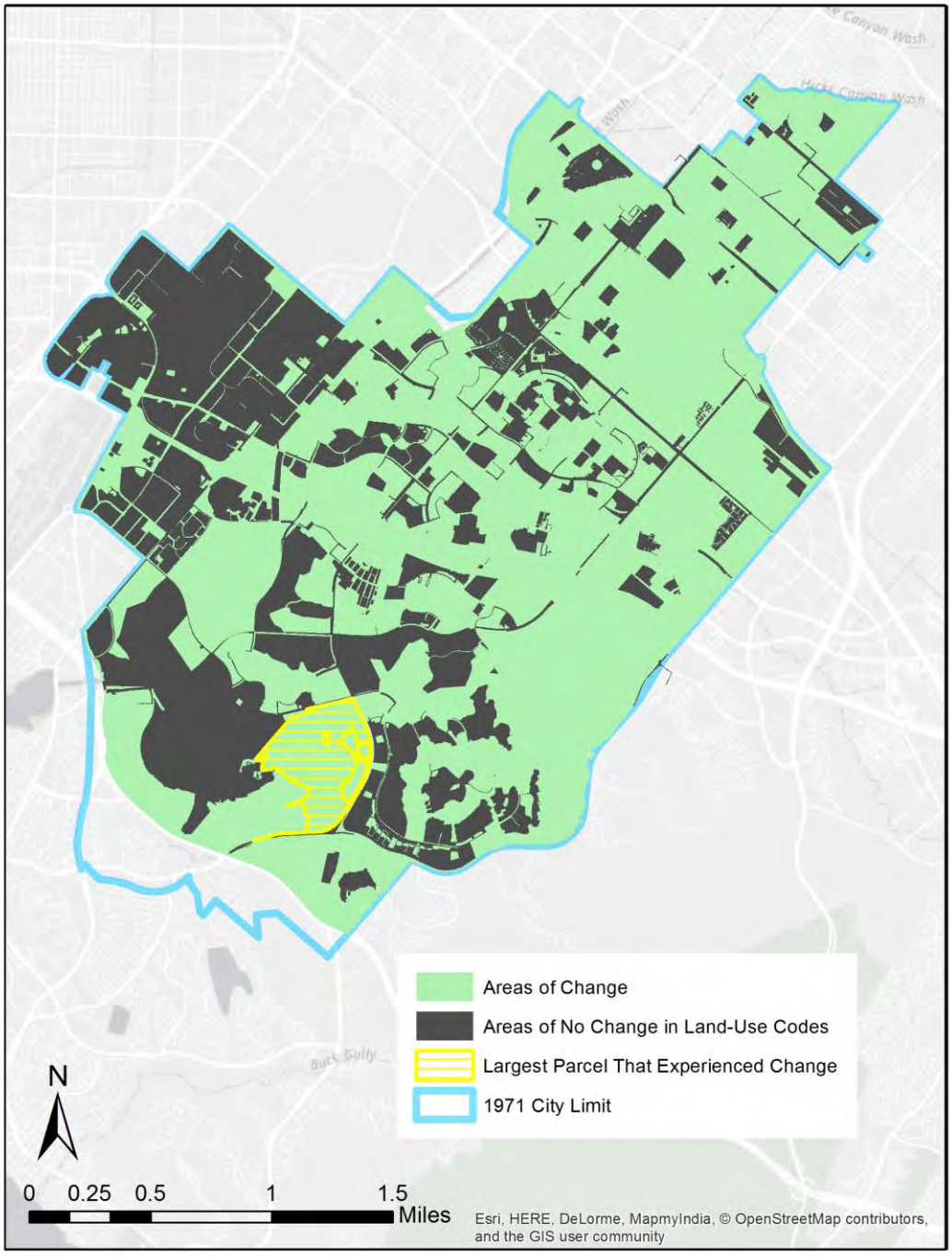

Figure 17 Areas of Change and No Change

4.1.2. Land Use Codes with the Largest Changes by Percent of Acreage

Even though changes to land use in the various residential categories was expected to have the most changes, the land use category with the most change by percent of acreage was Golf Course (Table 3 Largest Changes by Percentage of Acreage Almost half (45.4%) of the 1973 Golf Course land is now categorized as Open Space. These 234 acres that changed are at the San Joaquin Marsh and Wildlife Sanctuary and its neighbor, the Michelson Water Reclamation Plant between Campus and Michelson Drives. The next biggest changes were in residential and will be discussed in section 4.2.

Table 3 Largest Changes by Percentage of Acreage

	Percent of a land use area that changed and what it changed to
1	45.4 % of Golf Course area changed to Open Space
2	34.8 % of Medium-High Density Residential changed to High Density Residential
3	34.5 % of Medium Density Residential changed to Low Density Residential
4	26.9 % of Low Density Residential changed to Open Space
5	26.0 % of Parks changed to Golf Course
6	23.7 % of Institutional changed to Commercial

This corner of Irvine experienced quite a few changes. What was to be a golf course is now designated Open Space, in pink below (Figure 18). The blue "U" area designates the Michaelson Water Reclamation Plant though that has expanded. The housing and retail sections of this block were not built and are now also part of the water reclamation area. Used water starts the reclamation process at the Michaelson plant and eventually goes into these ponds. All this water attracts birds and other wildlife so the Irvine Ranch Water District set this up as a wildlife sanctuary so people could hike and go birdwatching.

Figure 18 Golf Course to Open Space

4.1.3. Largest Areas of No Change

Only two land use codes remained mostly unchanged (
Table 4). Seventy-eight percent of Open Space (234 acres) remained Open Space and sixty-eight percent (1008 acres) of Education is still used as Educational. Nine elementary

schools on the 1973 map were never built, probably due to the City of Irvine downsizing the final population total for the city. Fewer residents means fewer schools are needed.

Table 4 Largest Areas of No Change by Acreage

	Percent of land use area where no change occurred
1	78.0 % of Open Space remained Open Space
2	68.4 % of Educational remained Educational
3	40.6% of High Density Residential remained High Density Residential
4	36.9 % of Roads acreage remained Roads
5	35.1 % of Park area remained Parks
6	33.6 % of Golf Course area remained Golf Courses
7	32.0 % of Low Density Residential remained Low Density Residential

4.2. Digging Deeper - Changes by Land Use Code

Although 120 out of 192 possible land use change code pairs had at least a few acres of change, only a few were chosen for a closer look. 166 change code pairs contained fewer than 150 acres of change. The largest acreage for one change pair was 1944 acres for Medium Density Residential changing to Low Density Residential (Figure 19).

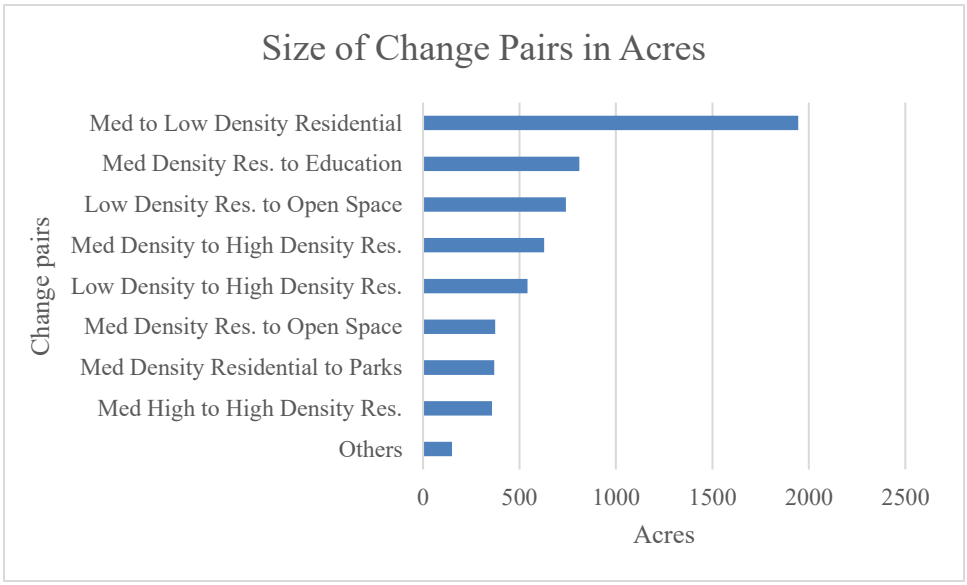

Figure 19 Size of Change Pairs in Acres

4.2.1. Open Space

Most of the Open Space land stayed the same, but this is also where the single largest parcel that changed codes occurred. Open Space was the land use code with the least change by percentage of acres. Only 22% changed on Irvine's General Plan between 1973 and 2017. Nearly all the change, 21.5%, occurred in just one area, the University of California at Irvine's arboretum. The plot was recoded from Open Space to Educational. This is just an artifact of recoding. Currently there is nothing there but an open field, but it abuts the 12.5-acre arboretum and the buildings for the UCI North Campus. This plot has about 2600 feet of prime real estate frontage along Jamboree Road, a major thoroughfare of the Irvine Business Complex. In August 1992, the Irvine city council passed resolution 92-128 which "allows 650,000 gross square feet of non-residential development (office, research and development, and support retail) and 300 dwelling units on UCI's North Campus" (City of Irvine 1992). As of the date of this study, it is still an open field.

4.2.2. Parks

For Parks, 35.1% of the acreage stayed the same. The largest change, at 26%, was a change to a Golf Course. This change was the Strawberry Fields Golf Course which opened in 1997. The second largest change to Parks, at 10%, occurred where Parks changed to High-Density Residential (Figure 20 Areas Where Parks Changed to High-Density Residential) Former park areas, in small bits here and there all over the city, were changed to High-Density Residential. This helps a little with Irvine's affordable housing problem.

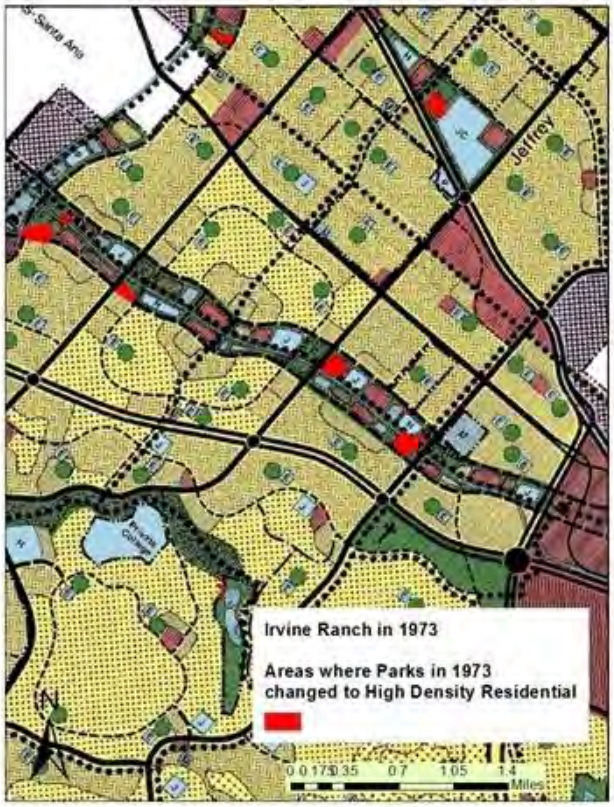

Figure 20 Areas Where Parks Changed to High-Density Residential

One area formerly coded as Parks was confusing. Highlighting only the changed acres showed only a portion of the Park Lane housing tract had been planned as a park (Figure 21).

What was going on? In 1973, there were three separate plots planned for that block, one Medium-High Density Residential (in red), one park (in olive), and one retail (in mauve). The shopping center was never built. What was built was only the park and the high-density residential so the park expanded northeast to include all the area which had been planned as retail, and a section of the original park area got added to the original high-density residential plot. This entire area was part of one of the original environmental corridors that didn't get built.

Figure 21 Plans for Four Land Uses in 1973 Become Two in 2017

4.2.3. Residential Density

The distribution of housing among the five residential density land use categories changed noticeably between 1973 and 2017 (Figure 22). The percentages for each residential category were calculated based on the total acreage in this study which was 17,290 acres. In 1973 the Medium Residential Density category encompassed 32.6 % of all the acres in the study and the High Density Residential was only 0.25 %. There were no acres of the Estate Residential

Density in the study area back in 1973. The “Other” category is for all the other land use categories in this study such as Industrial or Educational. This section looks specifically at the Residential sector.

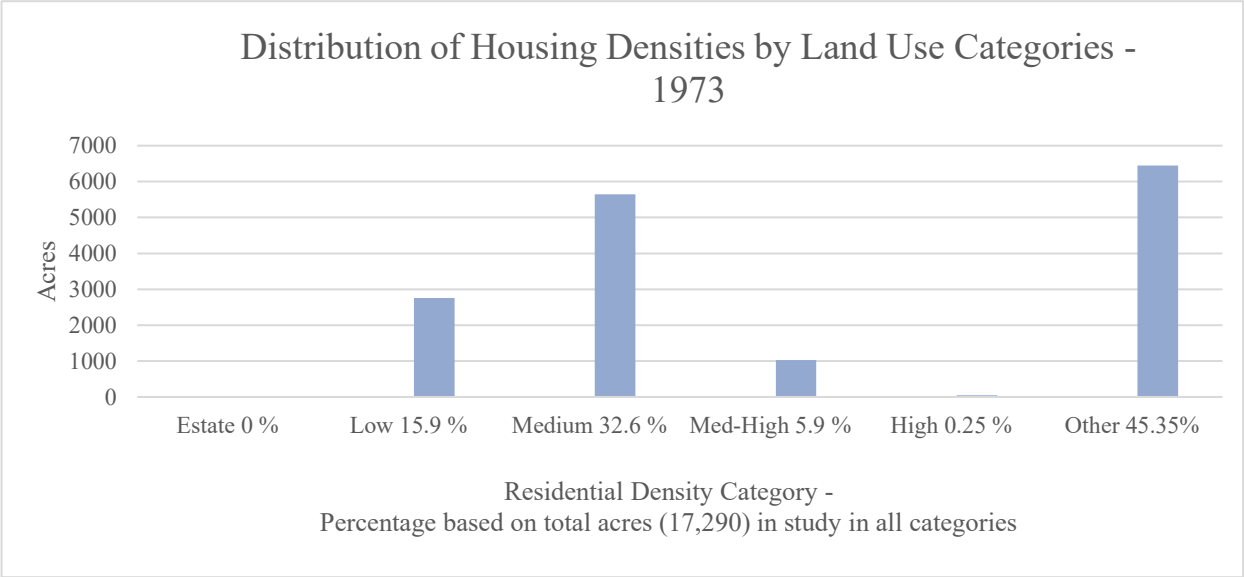

Figure 22 Distribution of 1973 Housing Densities

By 2017 the distribution of acreage among the residential density land use categories had changed (Figure 23). Now, the largest share of acreage is in Low Density Residential which had been at 15.9 % but is now at 17.6 % and an increase of 2.3 % of the total acreage in the study. The other large increase was in High Density Residential. From almost nothing in 1973, 0.25 %, to a significant 12.1 % in 2017, this category had the biggest increase at 11.85 %. Also of note in comparing the two charts is how the share of acreage among the residential categories is more balanced. In 1973, the land distribution ranged from 0 % to 32.6 % among the residential categories. By 2017, the same categories now only range from 0.15 % to 17.6 %.

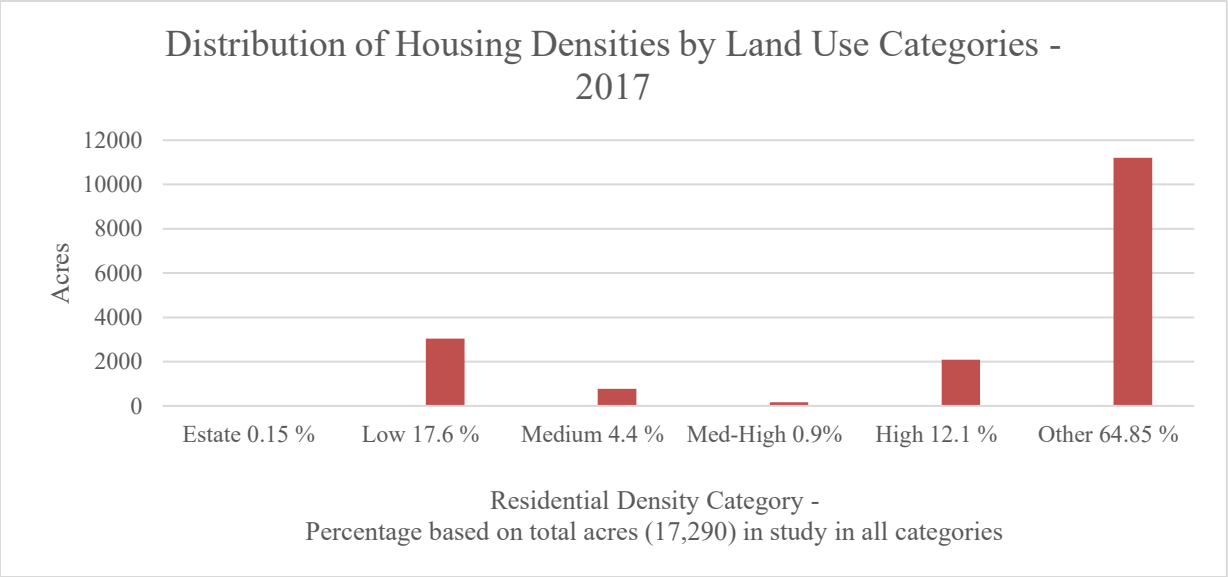

Figure 23 Distribution of 2017 Housing Densities

4.2.4. Low Density Residential

Most of the change to the 1973 code for Low Density Residential went to Open Space and High Density Residential. Almost a third, 32%, of the original Low Density Residential acreage stayed Low Density Residential but 26.9 % changed to Open Space. Three areas make up the bulk of this Low Density Residential change to Open Space. They are highlighted in pink on a portion of the 1973 General Plan provided by The Irvine company (Figure 24).

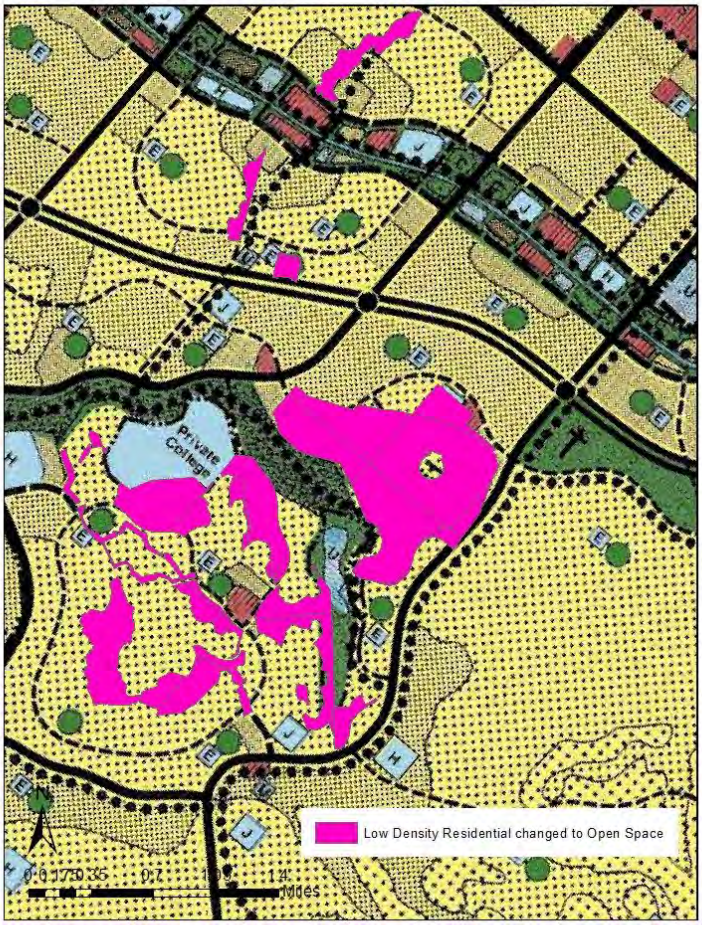

Figure 24 Areas Where Low-Density Residential Changed to Open Space

The first part is the addition of two large lakes into the Woodbridge residential development. On the 1973 map there is no provision for any lakes. When Woodbridge was constructed, both a North Lake and a South Lake, encompassing 55.9 acres, were included for recreational activities. The second part is the Open Space within the Turtle Rock development (Figure 25). This open space does not have any name such as preserve or wilderness. According to people who have lived there it is unbuildable open space that people are discouraged from entering. All the extra open space makes the homes there feel more exclusive.

Figure 25 Open Space in Turtle Rock from Google Maps

The third section is an area called Quail Hill. It is the large pink section in the upper right of Figure 24. Quail Hill was planned, in 1973, as Low-Density Housing, but the land is now part of the Irvine Land Conservancy and is used for hiking. In 1989, Irvine adopted a plan to permanently preserve 9,500 acres of open space. Quail Hill was part of this Irvine Open Space preserve.

4.2.5. Where Residential Density Increased

The areas where residential density went from a lower residential density code in 1973 to a higher density code in 2017 included six different change pairs (Figure 26). If residential density was going to change, and increase in density would be expected more than a decrease in density. Over one thousand of the Low Density residential parcels changed to Medium Density, Medium-High Density or to High Density with the most, 744 parcels, moving up just one level to Medium Density.

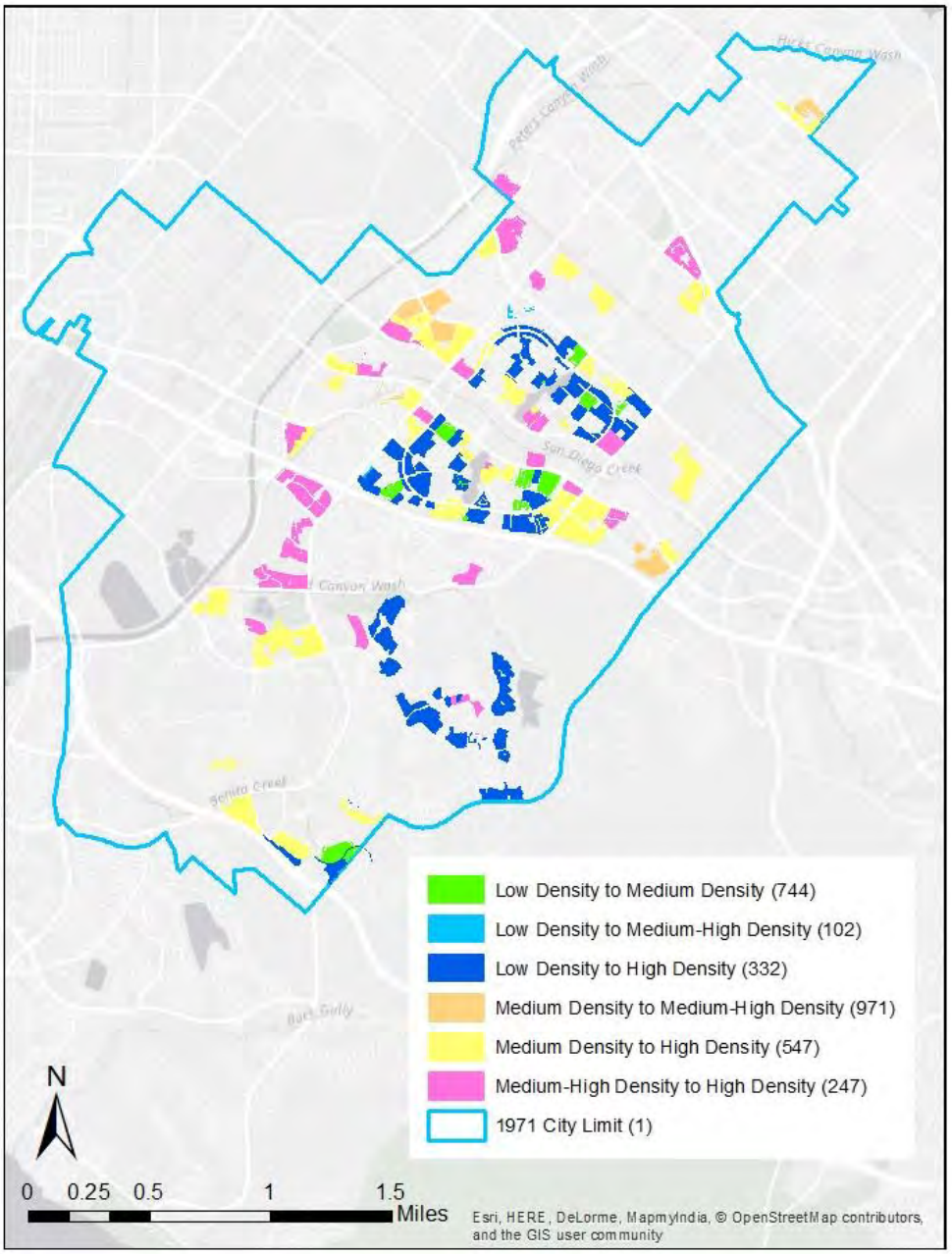

Figure 26 Areas of Residential Density Increase with Count of Parcels that Changed Codes

4.2.6. Where Residential Density Decreased

The parcels where residential density increased are spread out among six different change pairs, but most of the decrease in residential density occurred in only one change pair, the Medium Density Residential to Low Density Residential pair (Figure 27). There is no obvious reason for this change though the pattern of blocks matches up somewhat with the pattern of clear spaces on one of the Irvine Company's early maps (Figure 28).

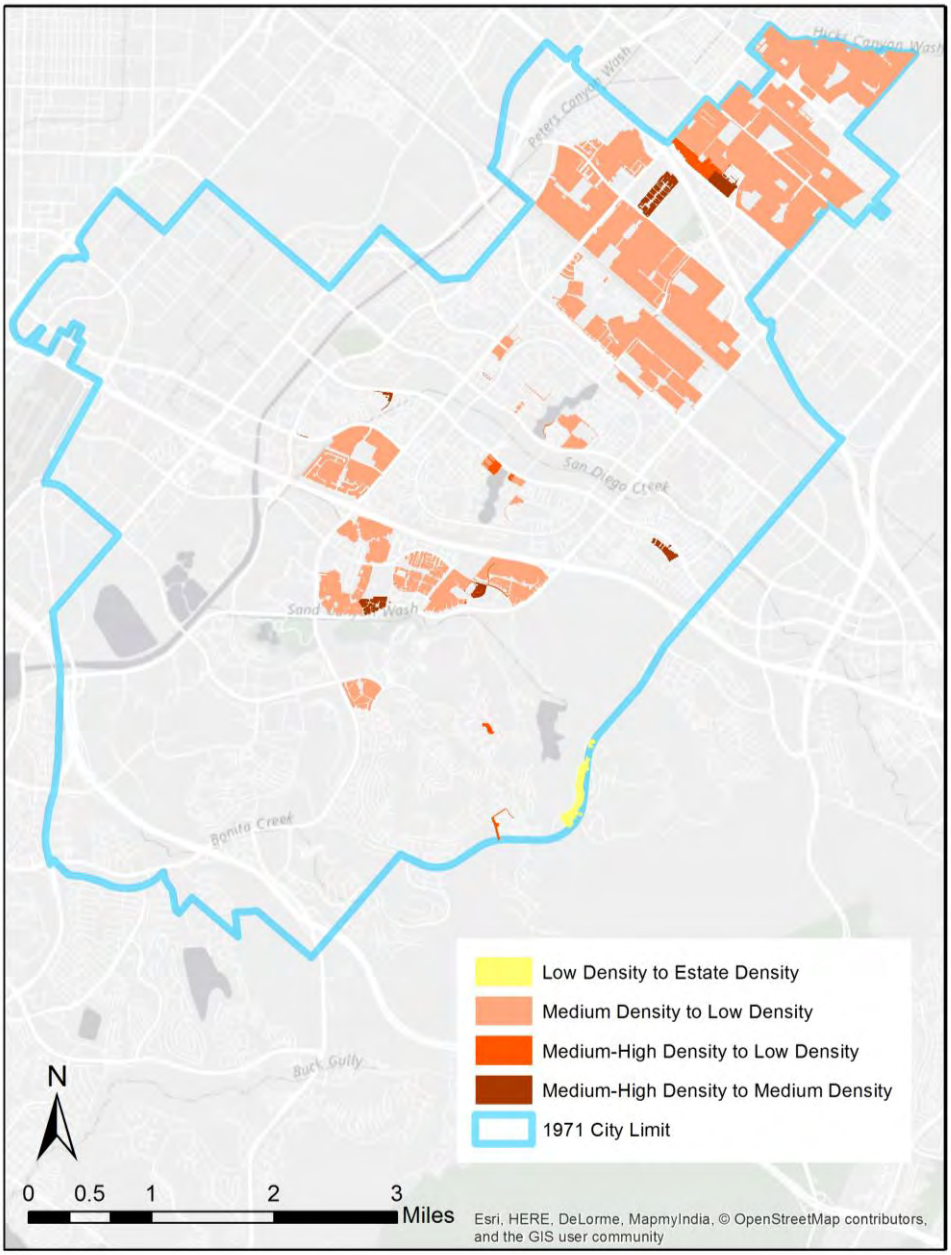

Figure 27 Areas Where Residential Density Decreased

The clear blocks on this late 1960s map were lots that had been sold off early in the 1900s to help pay for irrigation and other expenses of the ranch. The Irvine Company would not have had control over how, or if, the farmers would develop those plots. Perhaps that is why the entire area is coded as Medium-High Density Residential on the Irvine Ranch 1973 land use map.

Figure 28 Un-coded Blocks in Pre-1970 Map

Some of these housing tracts were already being built by the date of incorporation. College Park (Figure 29), a housing tract at the corner of Culver and Walnut near the 5 freeway, had already been planned and building had begun by December 1971. In the 1973 map, these homes are coded as Medium Density Residential. Even in the 1977 "final" General Plan officially adopted by the city council, College Park is still coded as Medium Density Residential. In 2017, however, College Park is coded as Low Density Residential. There are 835 homes in 178 acres which puts the dwelling units per acre at 4.69. This puts College Park into the Low Density Residential category.

Figure 29 The Housing Tract of College Park

4.2.7. Irvine Business Complex

The Irvine Business Complex is one of the largest business complexes in Orange County, California. Its 2,700 acres extend from the District Shopping Center in Tustin south to the John Wayne Airport. It is bounded on the northwest side by the Newport Beach Freeway and along the southeast side by the San Diego Creek. The University of California Irvine and the San Joaquin Wildlife Sanctuary are both just to the east. The complex is within easy reach of three major freeways, the Newport Beach (55) freeway, the San Diego (405) freeway and the Santa Ana (5) freeway (Figure 30).

The Irvine Business Complex (IBC) was developed, starting in the 1970s, as a commercial and industrial center. It was meant to include hotel, restaurant, commercial, retail,

industrial and office space. In the 1973 General Plan map, the entire area now covered by the IBC was coded as Industrial and Commercial. The City of Irvine needed more housing and workers wanted to be closer to their jobs. In a survey in 2010, 25-40% of the current IBC residents also worked in the IBC. So, the city created the Irvine Business Complex Residential Mixed-Use Overlay Zone to allow residential development within the IBC. Over 90 acres, 3.7 %, of the Industrial area in 1973 has be changed to IBC land use codes which allow residential units. In this study, all the change is contained in one code "IBC," but before consolidating codes, these parcels were classified as IBC Mixed Use, IBC Multi Use, or IBC Residential.

Following New Town principles, the City of Irvine has tried to include parks, sidewalks, public transportation, varied age and income groups, a mixture of housing types and place identity with these new residential developments. There is some public transportation in the area. The Tustin Metrolink train station is only 1.5 miles to the north. In 2008, the iShuttle started taking commuters to and from the IBC. However, the IBC has not been very pedestrian friendly and there were no parks. Several streets have no sidewalks. After the city changed the General Plan for the area to allow residential units, the new areas will have sidewalks. Local parks are also a new addition to the IBC. The plan is to add new parks such that each resident can live within ½ mile of a local park. In the northern section of the IBC, residents will have the Bill Barber Marine Corps Memorial Park, but new parks are needed for the residential neighborhoods in the southern section of the IBC.

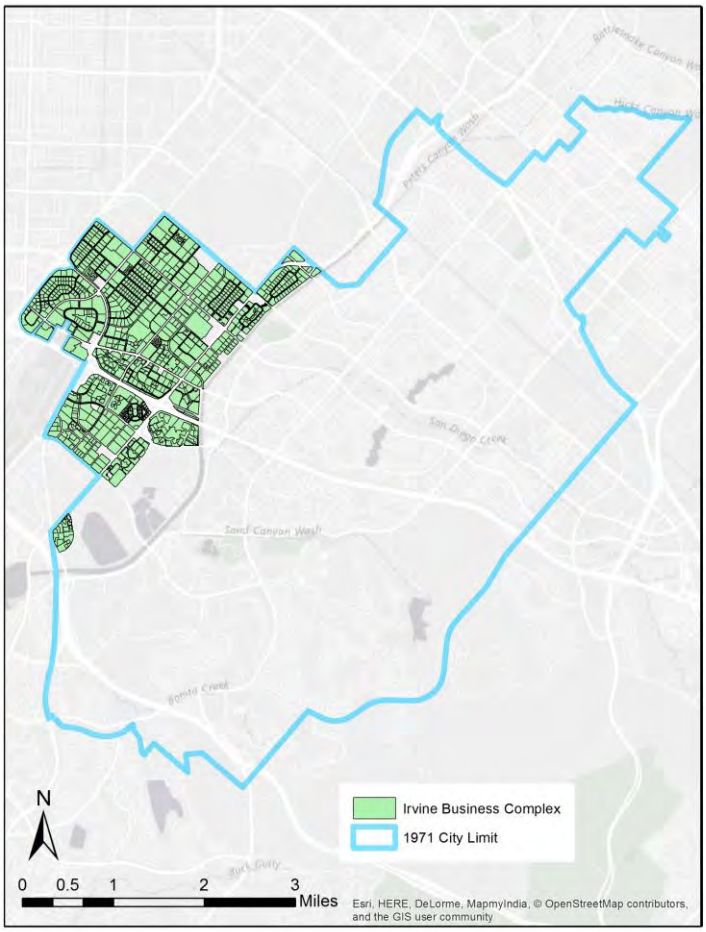

Figure 30 The Irvine Business Complex

Chapter 5 Discussion and Conclusions

Many land use changes were found comparing the 1973 General Plan land use map of the Irvine Ranch with the 2017 General Plan land use database. Changes to housing and Open Space are highlighted in the summary along with a discussion on how the City of Irvine is following New Town movement principles. There were many limitations to this study which are addressed in section 5.2. Recommendations for future studies and potential uses of this work are detailed in the final section, 5.3.

5.1. Summary of Findings

There were some surprises found by this study. Housing density changed in some unexpected ways and the amount of land devoted to Open Space greatly increased. Since this study only looked at land use within the 1971 City of Irvine boundary, land use totals and percentages are not representative of Irvine today for areas outside the 1971 boundary.

5.1.1. Housing Density Changes

There were both expected and unexpected changes in residential density between 1973 and 2017. As expected, several bits and pieces all over Irvine experienced and incremental increase in housing density. An expected effect of the increase in residential population is a filling of open space with needed housing. Another result could be an increase in housing density by replacing houses with apartments. However, the opposite happened in some parts of Irvine during the years under investigation. Hundreds of parcels around the 5 freeway went from Medium Density Residential on the 1973 General Plan to Low Density Residential in the 2017 database. Also, many acres designated as residential in the 1973 master plan have become Open Space.

5.1.1. Open Space

Major changes were not predicted in this land use category. The large number of acres that change from Low Density Residential to Open Space was a big surprise. A cluster of parcels near Michelson Water Reclamation Plant changed from Golf Course to Open Space. It is surprising to lose golf course space but for decades there has been a push to save more open space.

5.1.2. New Town Principles

In many ways, the City of Irvine is still following its original New Town principles. Each village has some level of place identity through signage, architecture, and landscaping. The City of Irvine has a large percentage of acres devoted to open space. Every village has a school and at least one park. Housing ranges from apartments to large estates, though housing affordability remains a big issue. Business in the city has been very strong at various points in the study period. For example, in 2005, Forsyth found that there were more than 3 jobs available for every resident (Forsyth 2005, 89). There continues to be a focus on balance between work and play, housing and open space, and retail and industrial development.

In Pereira's plan for Irvine, there was to be a mass transit corridor running through the center of the city connecting the two business parks. This was based on a master plan for over 400,000 residents. When the total population was reduced in the 1977 vote to adopt a modified General Plan, there were no longer enough residents to support a mass transit system. However, the areas where the mass transit was to be built could still accommodate a system, so maybe someday this city will become less dependent on the automobile.

The village concept was mostly successful. Residents know which village they live in and often answer the question "Where do you live?" with their village's name when speaking with

other residents of Irvine. With two major freeways running across the middle of the city, there is a possibility the people in the villages will feel disconnected from the rest of the city. The City of Irvine has worked to unify the city and bring people from different villages together by offering hundreds of community classes and events such as exercise classes, free concerts in some parks, and community outreach meetings on issues like major General Plan updates. The latest *Inside Irvine* magazine has over 100 pages of things for residents to do together (City of Irvine 2017b).

Where the City of Irvine noticeably falls short is with affordable housing. Even though there are a variety of housing types and densities, Irvine is still known for a high cost of living. At the public meeting for input on the "Overview of General Plan Update" (City of Irvine 2016a), half of the attendees were complaining about the lack of affordable housing. The other half, of course, were complaining about too much building and the increase in traffic ruining their quality of life.

5.2. Study Limitations

There were many limitations encountered during this study. Some limitations were expected such as getting accurate information out of an old map and the databases having a few typos. Other limitations were not expected such as having parcels of hugely different sizes which makes comparisons difficult.

5.2.1. Errors

There is plenty of room for errors in this study. Digitizing the areas on the historical map was done manually so there is likely to be some error in the process. Perhaps a curve would have been more accurately digitized with 50 points but only 20 were used. Parcels can be given the wrong land use code both in the City's parcel dataset and in this study's digitization of the 1973 general plan map. Digitizing with the Auto Complete option turned on made for many tiny errors

when the decision was made to go back and digitize road parcels for the 1973 dataset. There is a possibility of slight misrepresentations in percentages with the land use change pairings due to rounding.

5.2.2. Historical Maps

Most of the early General Plan land use maps for the Irvine area were not very detailed as to the exact boundaries of each type of land use element. The maps from the 1960s were all in black and white and the 1977 map, which was voted in as the official General Plan land use map, was all in sepia tones. Historical maps that employed a wide variety of colors are easier to decipher. The best historical maps for use with a GIS are detailed, clear, without holes or huge wrinkles and in solid colors.

5.2.3. Parcel Sizes

Parcel sizes in 2017 vary a great deal. The smallest parcel is a 1.59 square foot sliver while the largest single parcel was 340 acres. This parcel is the residential land on the UCI campus that was discussed in section 4.1.1. Such a huge variance in parcels sizes might under- or over-represent some change pairs. Ten small housing parcels changing is very different from ten huge open space parcels changing. The areas changed can differ by hundreds of acres. Changes by parcel count are not a reliable indicator of the magnitude of a change-pair's effect on land use.

5.2.4. Land Use Codes

The 2017 City of Irvine General Plan land use element codes were consolidated to make this study more workable. There are 86 different land use codes in the 2017 dataset but only 12 were used in the 1973 map. With current codes consolidated from 86 down to 16, there were potentially 192 change code pairs instead of 1,032. A study not limited to consolidated codes

might reveal a different story. This study did not parse out whether changes to High Density Residential affected more condominiums versus apartments or whether changes to Parks came from Neighborhood Parks more than from Regional Parks. There could be important stories in those details.

5.2.5. Problems with Roads

The roads in the 2017 database caused problems. Since the 1973 historical map only depicted major roads, all road parcels in the 2017 database that were not part of the major roads were to be recoded to match the type of block or tract they were in. For example, roads inside a housing tract were recoded with that housing tract's residential density land use code or roads inside a business park would be recoded as commercial. In some parts of Irvine, the road parcels are created so that the entire parcel can be coded with one land use code (Figure 31). In the picture below, each road parcel in pink is either inside the housing tract or completely outside. The small entryway road parcels end at the road. This makes it easy to code something as road or housing.

Figure 31 Road Parcels That Are Easy to Recode

Other road parcels were not easy to recode (Figure 32). Some sections of the 2017 map were digitized with longer parcels for the roads. Sometimes these parcels started inside a housing tract, or a business park, and continued outside to the main roads. Sometimes they even kept going around corners. To separate those polygons into parcels that could be coded differently would have meant adding new parcels to the 2017 database. The decision was made to not alter the number of parcels and make note of the error caused by not having all roads coded appropriately. This means the acres coded as roads will be off and the acres of some of the residential density codes will be off.

Figure 32 Road Parcels That Are Not Easy to Recode

5.3. Recommendations for Future Research

There are many directions for further research after this study. A future study could greatly expand the acreage to the current city limit and/or use all the unconsolidated land use codes. Another interesting direction would be to do similar studies on other large master-planned communities and compare the results with this study. The database developed here could be used in studies about Irvine looking for explanations as to why Irvine is one of the safest cities in the US.

5.3.1. Expand the Datasets

This study focused on the City in 1971 and a condensed set of 2017 land use codes. In 1971, when the City of Irvine was formed, it had only 28.3 square miles but the city has grown to over 66 square miles and could grow even more. A future study could compare the Irvine

Company's 1973 General Plan or the City of Irvine's 1977 General Plan to the current land use database and see how land use has evolved over time. There were only 12 land use codes for 1973 but 86 different land use codes in the 2017. Expanding the potential 192 land use change code pairs to 1032 could be more informative but it would be a lot more work.

5.3.2. Study Other Large Master Planned Communities

Several master-planned communities have been built in the United States since the 1960s. Irvine, as a master-planned community, has been compared with the Woodlands in Texas and Columbia in Maryland before, but not with a GIS or studying land use changes. Are more recently designed and built master-planned communities more likely to stick to the original plan or did other places change more?

5.3.3. Potential Uses of Work

This work could be used as data for studying why and when changes get made to the General Plans of master-planned communities and which sectors of the community are behind those changes. The method developed here could be used to study General Plan land-use changes between other years too. There were other General Plan overhauls for the City of Irvine in 1989 and 1999 also that could be studied.

It would be very interesting to study the relationship between this master planned community and some social metrics. The City of Irvine has been ranked the safest city in America several times, and Irvine schools are also ranked as being among the best. Is there a correlation between this city implementing this master plan based on New Towns ideals and the achievements in community safety and education?

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Appendix A Land Use Code Consolidation 2017

Feature	Description	Consolidated Code	New Category
1100	Agriculture	1300	Open Space
1200	UC Natural System	1300	Open Space
1300	Open Space	1300	Open Space
1310	Landscape Maintenance	1300 or adjacent lot code	Varied
1400	Fuel Modification	1300	Open Space
1510	Regional Park	1510	Parks
1520	Community Park	1510	Parks
1530	Neighborhood Park	1510	Parks
1540	Private Park	1510	Parks
1550	Golf Course	1550	Golf Course
1610	Lakes	1300	Open Space
1620	Reservoir	1300	Open Space
1630	Channel	1300	Open Space
1640	Basin	1300	Open Space
2100	Estate Density Residential	2100	Estate Density Residential
2200	Low Density Residential	2200	Low Density Residential
2300	Medium Density Residential	2300	Medium Density Residential
2400	Medium - High Density Residential	2400	Medium -High Density Res.
2500	High-Density Residential	2500	High-Density Residential

2510	Condominium	2500	High-Density Residential
2520	Apartment	2500	High-Density Residential
2600	Common Lots	1300 or adjacent lot code	Various
2610	Parking	3100	Roads
3110	Public	3100	Roads
3120	Private	3100	Roads
3140	Path	3100	Roads
3190	Abandoned ROW	3100	Roads
4100	Neighborhood Commercial	4100	Commercial
4200	Community Commercial	4100	Commercial
4300	Vehicle-Related Comm.	4100	Commercial
4400	Commercial Recreation	4100	Commercial
4500	Regional Commercial	4100	Commercial
4600	Retail Office	4100	Commercial
4610	Office	4100	Commercial
4700	Urban Commercial	4100	Commercial
4800	Irvine Garden Commercial	4100	Commercial
5000	IBC Mixed-Use	5100	Industrial
5100	IBC Multi-Use	5100	Industrial
5200	IBC Industrial	5200	IBC
5300	IBC Residential	5100	Industrial
5500	Health Care	5400	Institutional
5510	Hospital	5400	Institutional
5530	Medical Office	5400	Institutional

6110	Elementary School	6100	Educational
6120	Middle School	6100	Educational
6130	High School	6100	Educational
6140	College/University	6100	Educational
6150	IUSD Administration	6100	Educational
6160	Private School	6100	Educational
6170	Child Care	5400	Institutional
6180	Senior Center	5400	Institutional
6190	Church/Temple	5400	Institutional
6210	Public Services	5400	Institutional
6220	City Hall	5400	Institutional
6230	Corp Yard	5400	Institutional
6235	Multi Service Center	5400	Institutional
6240	Police	5400	Institutional
6250	Fire Station	5400	Institutional
6260	Post Office	5400	Institutional
6270	Library	5400	Institutional
6280	IRWD	5400	Institutional
6290	Edison	5400	Institutional
8010	Freeway	8000	Toll Roads/Easements
8020	Toll Road	8000	Toll Roads/Easements
8030	State Board of Equalization	8000	Toll Roads/Easements
8040	SBE Railroad ROW	8000	Toll Roads/Easements
8060	OCFCD access roads	8000	Toll Roads/Easements

8070	SCE Easement	8000	Toll Roads/Easements
8080	Public Utilities Easement	8000	Toll Roads/Easements
8090	Slope/Drainage Easement	8000	Toll Roads/Easements

Appendix B Land Use Change Pairs in Acres with Percentages of 1973 Area of Change

	1973 Land Use Codes												
	Open Space	Parks	Golf Course	Low Density Res.	Medium Density Res.	Med-High Density Res.	High Density Res.	Roads	Comm.	Indus.	Inst.	Educ.	Total acres in 2017
2017 codes													
Totals	**299.80**	**704.06**	**427.53**	**2753.62**	**5642.83**	**1027.08**	**43.85**	**1372.51**	**1027.97**	**2414.84**	**101.37**	**1474.61**	**17290.07**
Agri.	0	0	1.02	0	7.85	0	0	0	0	0	0	0	8.87
	~	~	0.20%	~	0.10%	~	~	~	~	~	~	~	
Open	233.87	43.93	194.04	740.15	373.41	114.66	9.67	78.02	48.25	14.34	21.76	12.15	1884.25
Space	78.1%	6.20%	45.50%	26.8%	6.62%	11.20%	22.1%	5.6%	4.70%	0.60%	21.50%	0.80%	
Parks	0	247.17	0.95	154.65	369.58	63.63	0	51.9	65.14	0.42	0.8	12.04	966.28
	~	35.10%	0.20%	5.62%	6.50%	6.20%	~	3.70%	6.30%	~	0.70%	0.80%	
Golf	0	183.31	143.77	67.36	148.03	0	0	0.22	43.03	0	0	0	585.72
Course	~	26.00%	33.60%	2.44%	2.60%	~	~	~	4.20%	~	~	~	

Estate	0	0	0	24.95	0.01	0.16	0	0	0	0	0	0	25.12
Density	~	~	~	0.91%	~	~	~	~	~	~	~	~	
Low	0	3.94	0	880.25	1944.93	38.87	0	110.74	16.73	0	0	44.86	3040.32
Density	~	0.60%	~	31.90%	34.5 %	3.80%	~	8.00%	1.62%	~	~	3.00%	
Med	0	12.30	0	97.60	535.37	64.97	0	29.06	4.45	0	3.63	16.93	764.31
Density	~	1.70%	~	3.54%	9.49%	6.30%	~	2.10%	0.40%	~	3.60%	1.10%	
Med-hi	0	6.8	0	5.78	97.16	21.21	0	7.13	11.99	0	8.97	9.06	168.10
Density	~	0.90%	~	0.21%	1.72%	2.10%	~	0.50%	1.20%	~	8.80%	0.60%	
High	0	71.71	13.81	542.26	627.17	357.04	17.77	107.28	222.60	0	10.18	121.37	2091.19
Density	~	10.20%	3.20%	19.69%	11.11%	34.80%	40.5%	7.80%	21.60%	~	10.00%	8.20%	
Roads	1.44	37.03	7.72	156.48	260.86	79.36	2.06	506.25	68.92	170.44	6.6	67.3	1364.46
	0.40%	5.30%	1.80%	5.68%	4.62%	7.70%	4.70%	36.90%	6.70%	7.10%	6.50%	4.60%	
Retail	0	43.13	3.86	0	191.76	101.72	5.64	40.95	264.67	64.87	23.96	62.93	803.49
	~	6.20%	0.90%	~	3.40%	9.90%	12.9%	2.90%	25.70%	2.70%	23.60%	4.30%	
Indust.	0	4.65	18.45	0	0	0	0	47.96	106.66	**1991.13**	0	0	2168.85
	~	0.70%	4.30%	~	~	~	~	3.50%	10.37%	82.50%	~	~	
IBC	0	0	0	0	0	0	0	0	0	90.7	0	0	90.7
	~	~	~	~	~	~	~	~	~	3.70%	~	~	
Inst.	0	27.64	43.91	14.27	71.77	17.55	0	5.46	55.90	19.45	15.49	95.32	366.76

	~	3.90%	10.20%	0.52%	1.27%	1.70%	~	0.40%	5.40%	0.80%	15.30%	6.50%	
Educ.	64.49	13.67	0	10.83	810.16	106.13	4.27	22.16	21.32	2.33	0	1007.76	2063.12
	21.5%	1.90%	~	0.39%	14.3%	10.30%	9.70%	1.60%	2.10%	0.10%	~	68.30%	
Rights	0	8.78	0	59.04	205.00	61.76	4.43	365.37	98.31	61.57	9.96	24.89	899.11
Of Way	~	1.20%	~	2.14%	3.6%	6.00%	10.1%	26.60%	9.61%	2.50%	9.80%	1.70%	
1973 Totals	100%	99.9%	99.9%	99.9%	99.9%	100%	100%	99.7%	99.9%	100%	99.8%	99.9%	17290