Geographic Information Systems as a tool for Floodplain Management and Risk Assessment

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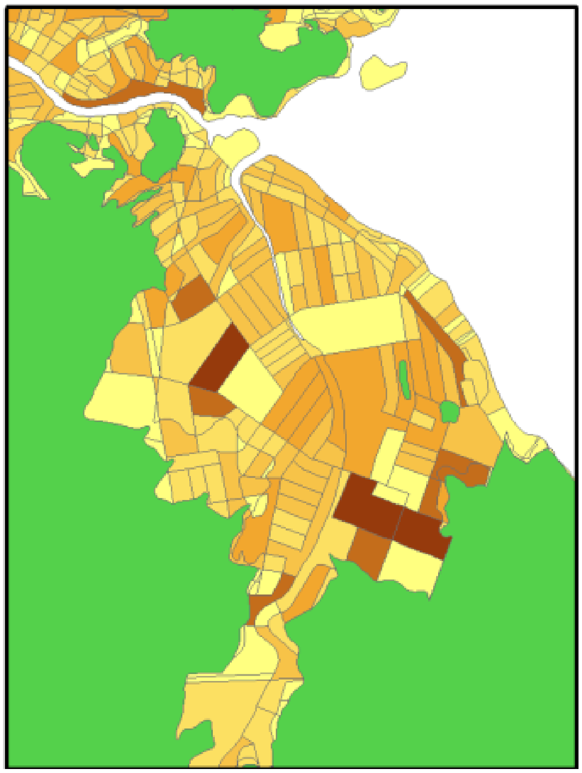

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ABSTRACT

This project created a methodology to estimate population and generate population and population density maps within the floodplains of San Juan, Puerto Rico. A survey about flood insurance, flood awareness, and flood damage mitigation was also conducted. The methodology uses aerial photographs, Census block data, and FIRM data and demonstrates the application of ArcGIS for map creation and population estimations in other floodplain regions. Analysis of the survey data allowed comparison of flooding and flood response in different communities. This data and methodology will be used by La Junta de Planificación to improve resource allocation and flood damage prevention.

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AUTHORSHIP

The completion of this project depended on the equal contribution of each member.

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EXECUTIVE SUMMARY

The population of San Juan rapidly increased throughout the first half of the 20^{th} century. This influx of population caused slums to grow in the poorer areas of the city. Although the government of Puerto Rico took measures to reduce the growth of slums, including the construction of new housing projects, more and more people moved onto all the available land. Much of this land is located in floodplains. The residents of these areas risk loss of life and property because of the likelihood of flooding in these sections of San Juan.

A floodplain is an area close to a river, stream, or body of water and subject to flooding. The Federal Emergency Management Agency (FEMA) assigns floodplains designations indicating the risk faced by residents. La Junta de Planificación, Puerto Rico's Planning Board, was interested in learning more about the number of people living in the floodplains to facilitate more appropriate actions being taken to prevent loss of life and property. This project had the following objectives:

1. Develop and test a methodology to estimate the population in floodplain regions. The methodology involved creating population and population density maps of the floodplains in the municipality of San Juan.
2. Administer a comprehensive survey to residents of floodplains in various socio-economic classes to better understand their knowledge of flooding and flood insurance. The analysis of the survey data included drawing general conclusions and comparing responses from different communities.

La Junta de Planificación was most interested in the development of a methodology to determine the population in floodplain regions. This methodology will be used by La Junta de Planificación to estimate the population of floodplains outside of San Juan. This information will help to allocate resources more efficiently during flooding emergencies. The maps created using this methodology show where the population is densest, so more effective procedures can be developed that take into account potential evacuation bottlenecks.

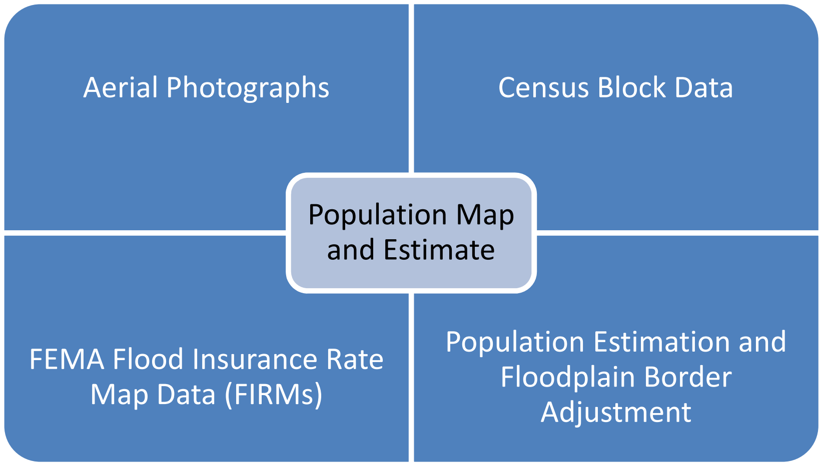

Figure 1: Population Map Information Sources

The first step in making the population maps was to collect the data. As shown in Figure 1, the data for the population estimation came from a number of sources. This data came from two databases and was uploaded into a Geographic Information System (GIS) called ArcGIS 9.2. This program displayed all the information as geospatial data and allowed for its manipulation to create both population and population density maps that could then be used to estimate the population in floodplains in the municipality of San Juan. The team first obtained San Juan aerial photography provided by the United States Army Corps of Engineers, Jacksonville district. These aerial photographs had high enough resolution that with ArcGIS, individual buildings could be seen.

Census block data was obtained from a database maintained by La Junta de Planificación. The Census Bureau divides Puerto Rico into small polygons called Census blocks, and the GIS meta-data associated with each block includes information such as household size, average people per household, population, and other demographical information. FEMA Flood Insurance Rate Maps (FIRMs) were obtained from FEMA that showed the areas of San Juan in floodplains and the level of risk the residents face. This information was overlaid with the aerial photographs and Census blocks to give a picture of all Census blocks that were fully or partially inside a floodplain area. The aerial photographs were still visible beneath the FIRM data, allowing individual buildings to be counted.

The group then counted the buildings in each Census block in each floodplain. A ratio of buildings inside the floodplain to the total number of buildings was then calculated for each

Census block. For the estimation of population, the team multiplied the ratio of buildings in the floodplain by the population of the Census block, resulting in an estimate of the population in the floodplain. This population data was then entered into ArcGIS to create population maps. The calculation of Census block area made the creation of a population density map possible. Using these maps, ArcGIS can estimate the population of an arbitrary floodplain. The methodology for the estimation of population and creation of the maps is one of the main deliverables of this project. The methodology created in this project is user-friendly and can be used by someone who has little experience with the software.

The second objective of the project was to create and administer a survey for the Planning Board of Puerto Rico. This survey contained demographical questions as well as questions regarding flood frequency, height, flood insurance, and flood damage mitigation. The goal was to take a stratified sample from flood zones in San Juan, covering a number of socio-economic classes. 418 surveys were collected from five different communities over four days.

The greatest obstacle that the group faced during the administering of this survey was the language barrier. The project liaison, Dr. Angel David Cruz Baez of the University of Puerto Rico Department of Geography, helped the team locate students to assist in administering surveys verbally while recording the answers on a printed survey. The data was then analyzed using Statistical Package for the Social Sciences (SPSS) to compare the different communities and draw conclusions about flooding and strategies used to prevent flood damage.

At the conclusion of the project, the team presented the floodplain population estimation methodology, floodplain population and population density maps, and the survey data analysis to Dr. Cruz and Wilfredo Más of La Junta de Planificación in the form of a tutorial and final report. The population and population density maps, GIS data used to create the maps, population estimation tutorial, and raw survey data, and maps were also submitted electronically.

CHAPTER 1: INTRODUCTION

The number of people living in San Juan, Puerto Rico increased dramatically from the early 1900's to the 1970's and this influx of people facilitated the formation of slums where the standard of living is low (Mignucci, 2008). To deal with the growing slums in and around San Juan, the Puerto Rican government began building public housing projects over a period of two decades (Mignucci, 2008). The government of Puerto Rico constructed many of these residential projects on floodplains and other flood prone areas until the 1970's when federal and local laws prohibited people from building on or moving into these areas. Enforcement of these laws is difficult due to the high population densities in this area and the lack of alternative housing for the residents. Despite legislation against floodplain settlements, people continue to move into these areas in order to take jobs in the city and a large number of people are now living in these hazardous areas. Another issue facing floodplain residents are the laws regarding flood insurance. Federal laws require that residents have flood insurance in certain zones designated as floodplains and that after receiving an insurance payment the recipients must make improvements to their homes in order to prevent future damage. The number of residents without insurance or receiving repeated payments for flood damage is not known.

A floodplain is an area in close proximity to a river, stream, lake, bay, or other body of water that is subject to flooding (H. Vargas, et al, 2010). The floodplain is made up of two parts, the floodway and the flood fringe. The floodway is the area that carries the bulk of the water away from the floodplain; this is usually a stream or river located in the center of the floodplain (Flood terminology, 2010). The flood fringe refers to the outer sections of the floodplain. The flood fringe, unlike the floodway, is not usually under water. In fact, for most parts of the year this area is dry enough for people to settle on. Those living on the floodplains find themselves in circumstances that are very dangerous during the rainy season.

Flooding is a large problem in Puerto Rico, especially in and around San Juan. In 2008, San Juan reported 54.7 inches (138.9 cm) of rainfall, just 0.15 (0.38 cm) less than the year before (National Weather Service, 2009). All of this rainfall does not necessarily fall slowly; hurricanes and other tropical storms cause periods of heavy rain during hurricane season, which runs from June through November. Between September 21st and September 23rd, 2008, some parts of Puerto Rico reported nearly 30 inches (76.2 cm) of rain due to Hurricane Kyle. This rain resulted in flooding that caused 5 deaths (Devastating floods, 2009). The amount of rainfall that Puerto Rico receives combined with its geography has created zones around San Juan that are at considerable risk for flooding.

Hurricane Katrina, which made landfall in the south-eastern United States in August, 2005, revealed the dangers associated with large numbers of people living in flood prone areas. The flooding that comes with a hurricane can leave thousands dead or homeless if proper emergency management plans are not in place and followed promptly at the beginning of a disaster. The flooding of the Mississippi river was responsible for 1,464 deaths (Louisiana Department of Health and Hospitals, 2006). Furthermore, thousands of people lost their homes and months later were still homeless (Van Heerden & Bryan, 2007). The governmental response drew criticism from scientists, politicians, and the press who all believed that the existing plans were inadequate and much of the damage could have been reduced. According to Ivor Van Heerden, a marine scientist whose model closely predicted the damage caused by Hurricane Katrina, New Orleans' "plan amounted to a 'good samaritan' response" that was "not good enough" and he states that the actions in the plan "could never evacuate more than mere thousands, when the problem was tens of thousands" (Van Heerden & Bryan, 2007). Proper plans for evacuation and mitigation of damages are essential for reducing loss of life and property when an emergency such as a flood threatens an area. With more available information and disaster planning already in place, flood risk mitigation can be rendered much more smoothly.

Puerto Rico's unique status as a free associated state within the United States allows it a certain degree of autonomy, with the local government headed by a popularly elected governor. Several agencies whose mission is to enhance the quality of life in Puerto Rico are at the governor's disposal. This study worked in conjunction with one such agency, La Junta de Planificación de Puerto Rico (The Planning Board of Puerto Rico). According to its mission statement, this body is dedicated to improving the lives of Puerto Rico's citizens through "conservation, protection, preservation of the natural environment…and economic progress" (Vargas, 2008). This body addresses issues involving zoning, provides forms and publications regarding health, safety and construction laws to the public, and has a library of maps of Puerto Rico. The problem facing La Junta de Planificación and the other organizations involved in emergency management in San Juan is that they do not know how many people would be affected by a serious flooding event. La Junta de Planificación does not have any information about the insurance that the residents of the floodplains may have or about the insurance claims that they have made in the past. The information on the location of floodplains provided by La Junta de Planificación will be vital in assessing risk to residents living in these floodplains.

This project took existing aerial photos, Census data from 2000, and flood maps and created layers from this data and combined them into one map which shows the number and density of people living in the regions designated as floodplains. This process will serve as a template for future efforts to estimate the population of floodplains in other areas of Puerto Rico. Additionally, a survey was conducted to collect information on the flood insurance status, flood awareness, and flood damage mitigation strategies of the residents of the floodplains.

CHAPTER 2: LITERATURE REVIEW

Throughout the past 150 years, social, economic, and environmental factors have led to the settlement of floodplains in Puerto Rico. Floods occurring in these areas often threaten the lives and property of the floodplain residents and the Puerto Rican government is trying to mitigate this risk, both by relocating the residents and by developing risk management strategies. This chapter presents the factors that led to settlement of floodplains, describes floodplains and the hazards they present, and summarizes floodplain insurance laws, regulations, and the current insurance situation. It also reviews ArcGIS and other software that this project used to incorporate population and flooding data into a population map of the floodplains.

2.1 History

There are two groups of people in Puerto Rico currently living in floodplains. The first group includes people who live in public housing built by the government of Puerto Rico prior to the 1970's, while the second group live in settlements built before flood zone regulations established in 1973. Both groups arrived in their respective situations because of a sharp increase in population density and a rapid rise in the overall population of San Juan. There simply is not enough safe and affordable housing or land for all of the people that immigrated to the San Juan area and many of them are forced to settle in floodplains.

Prior to the Spanish-American War, cash crops such as tobacco, sugar, and coffee controlled the Puerto Rican economy. When Spain ceded Puerto Rico to the United States after the Spanish-American War, several factors produced an emigration from the mountains to the coastal cities. In 1899, the island was struck by Hurricane San Ciriaco, causing not only immense loss of life, but also the destruction of the coffee plantations that had been the foundation of the Puerto Rican economy. Emigration from the mountains into the cities, especially into San Juan, was one of the few available paths for escaping this adversity (Picó, 1988).

After Hurricane San Ciriaco crippled the coffee industry, the sugar trade began to dominate the Puerto Rican economy. The Foraker Act, passed by the United States in 1900, opened Puerto Rico up to a substantial influx of American capital. Agricultural advances tripled the yield per acre on sugar farms owned by businesses based in the United States. However, as these advances were unavailable to most of the existing farms, many of the Puerto Rico-owned farms were forced out of business (Bryan, 2000). These farm owners were “forced to leave the haciendas and move to the cities or take jobs as hired hands and cut sugarcane” (Bryan, 2000). Due to this immigration, between 1898 and 1934, San Juan’s population increased by 105,000 (Mignucci, 2008).

During the 1940’s and 1950’s, another factor began to drive immigration to San Juan and other cities. Puerto Rico launched a program called Operation Bootstrap in 1947 which “was a massive effort to attract U.S capital and investors” to industrialize Puerto Rico (Bryan, 2000). The program offered tax exemptions, low interest loans, and research assistance to businesses from the United States. The industrialization of San Juan brought even more people to the city seeking work in the factories and manufacturing facilities. The population of San Juan rose from 237,537 in 1940 to 368,576 in 1950 (Mignucci, 2008). With industry and the population continually growing throughout the 1950’s, San Juan’s population reached 451,658 by 1960 (Mignucci, 2008).

Begun as a small, fortified city, San Juan simply did not have adequate living spaces for these immigrants within the city walls so they settled in the areas surrounding San Juan using materials they could salvage and the living conditions quickly became unsanitary (Mignucci, 2008). Taking notice of the slums growing outside of San Juan, the government of Puerto Rico founded the Homestead Commission in 1921. The Homestead Commission was authorized to establish settlements for workers around San Juan (Descartes, 1943). The Commission’s first act was to construct single-family homes in an area prone to flooding known as the Barrio Obrero (Mignucci, 2008). Construction on similar projects continued until the election of Luis Muñoz Marín to the office of governor in 1947.

Luis Muñoz Marín “committed himself to improve the living conditions of the poor through social justice and economic development programs” (Mignucci, 2008) which greatly changed the philosophy directing the construction of public housing in Puerto Rico. Muñoz Marín and his administration viewed large, multi-family buildings as only a temporary solution to low-income slums, preferring to build single-family homes to promote home-ownership (Dinzey-Flores, 2007). Muñoz Marín’s intention was for families living in slums to move into the public multi-family buildings until they could afford to buy a single-family home.

Although the Puerto Rican government never intended for people to live permanently in these buildings, the majority of families live “long-term and multi-generational lives” in public housing projects (Dinzey-Flores, 2007). Furthermore, the residents developed an attachment to their location and are proud of their neighborhoods and feel comfortable there even though these public housing projects are located in areas susceptible to flooding (Dinzey-Flores, 2007). Since the 1960’s the Puerto Rican government has been trying to reverse the trend of increased development and restrict the number of people living in public housing with the *Law for the Building Control in Flood Zone Areas* passed in 1961, and *Acts 75* and *76* passed in 1975 (Vargas et al, 2010). The chief restriction in these laws concerns development in floodplains. Although violations may technically result in fines or imprisonment and the demolition of the building or structure, these laws are normally difficult to enforce due to the number of structures already on floodplains (La Junta de Planificación, 1961).

Despite the laws against building or living in these areas, people remain because they have established communities in these areas, they have nowhere else to go, and it is difficult for the government of Puerto Rico to remove them. Not all of the slums were replaced with public housing projects and there are still illegal, informal settlements around San Juan. In one such community, called the Villas del Sol, the Puerto Rican government is trying to move the residents because it is located in an area that is dangerous due to the likelihood of flooding. The residents, some of whom have lived there for fifteen years, stated in August, 2009, that they are willing to fight to stay (CB Online Staff, 2009).

By January 27, 2010 the residents negotiated a timeline for leaving the settlement with the Puerto Rican Land Authority, hoping for either an exchange of land or an opportunity to buy land from the Land Authority (Vega, 2010). Both the community leaders and the Puerto Rican government are having trouble finding a place to house the 200 families that live in the Villas del Sol. Like the resident of the Villas del Sol, communities facing eviction or demolition of their homes are rarely able to find an alternative location. A potential solution, a 17-acre tract of land in Arecibo donated to the community by Eduardo Ibarra was later found to be in an “environmentally sensitive” area and the community could not legally relocate to that land (Vega, 2010).

The problems facing Puerto Ricans living in floodplains are difficult for the government to solve due to the lack of safe, available land. Therefore, the government is searching for methods to protect both the property and the lives of the people who live in these hazardous areas. Governmental agencies have had trouble creating these mitigation strategies because they do not have current population data from floodplains; in fact, the floodplain designations change with the publications of new flood maps.

2.2 Flooding

The consequences of living on a floodplain can be devastating regardless of the legality of the settlement. Floodplains are common on the island of Puerto Rico, and flooding is an important issue for citizens and government officials throughout the island. According to the National Flood Insurance Program (NFIP), "Flood risk isn’t just based on history, it’s also based on a number of factors: rainfall, river-flow and tidal-surge data, topography, flood-control measures, and changes due to building and development" (“Flood Risks Overview”, 2010). Unfortunately, Puerto Rico is frequently subject to all of these factors. To fully understand how and why the people situated on the floodplains experience hardships, it is necessary to know about floodplains in Puerto Rico and the causes of flooding.

A floodplain is an area of land "adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding" ("Flood terminology", 2010). Flooding is defined by the NFIP as "a general and temporary condition where two or more acres of normally dry land or two or more properties are inundated by water or mudflow" (“Flood Risks Overview”, 2010). A floodplain contains two regions, the floodway and the flood fringe. The floodway is defined by the NFIP "the channel of a river or stream, and the overbank areas adjacent to the channel" ("Flood terminology", 2010). The floodway discharges the majority of the flood water away from floodplain. In most cases there are strict laws and regulations that prevent development in the floodway (Vargas et al., 2010). The flood fringe begins on the outskirts of the floodway, and makes up the outer portion of the floodplain. The flood fringe is subject to regular flooding, yet development on a floodplain normally occurs in the flood fringe ("Flood terminology", 2010). Since a major component of this project was identifying the populations settled in the floodplains in the Municipality of San Juan, this definition was very useful.

The Commonwealth of Puerto Rico Office of the Governor Planning Board defines these terms in the Special Flood Hazard Areas Regulations Manual and are used in this investigation:

> "Floodplain – Usually dry, low- or semi-low lands susceptible to being inundated by waters from any natural source. These low areas usually lie next to a river, creek, brook, ocean or lake affected by the highest flood elevations known in the history of the region, or by the base flood, as illustrated in presently available studies and maps. Floodplain also means the Flood having a one percent (1%) chance of being equaled or exceeded in any given year, the 100 year recurrence, the Special Flood Hazard Areas"(Vargas et al., 2010)

> "Floodway – The bed of a river, brook or natural storm drainage, plus those portions of neighboring lands that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 0.30 meters. In case of a new detailed study (Zone A, section 7.02) taking into consideration fill deposit, Section 7.07, the maximum increase to be allowed will be 0.15 meters, as determined by the hydrologic-hydraulic study" (Vargas et al., 2010).

Although these definitions appear very similar to the more commonly accepted definitions, the differences are important. The major difference in the definition of floodplain is that, according to the Municipality of San Juan, a floodplain is only considered a floodplain if there is a "one percent (1%) chance of [the base flood] being equaled or exceeded in any given year." The Municipality of San Juan defines a floodplain in terms of measureable specifications, making it more difficult to determine if a region is a floodplain

Floodplains are very dangerous for many reasons. The risks associated with flooding change in Puerto Rico due to seasonal variance in rainfall. Flooding often occurs during hurricane season, between the months of June and November ("Hurricane Season", 1995). Hurricanes can cause a surge of water that causes flooding in its bays, rivers, and other waterways. For example, in 2008 after Hurricane Ike, John Marino wrote, "In Puerto Rico, the U.S. territory's southern coast was hardest hit by flooding. Several rivers, including the Rio Grande de Arecibo and Rio de la Plata, surged over their banks. Scores of roadways were flooded and two major highways were partly closed because of mudslides" (Marino, 2008). Storm surges are not the only danger hurricanes present. Hurricanes also increase rainfall, which results in flooding. In September of 1996, Puerto Rico received over 12 inches (30.5 cm) of rain in a 30 hour period due to Hurricane Hortense (Bennett, 1996). Similarly, in 2008 between September 21st and September 23rd, some parts of Puerto Rico reported nearly 30 inches (76.2 cm) of rain, which resulted in flooding that caused 5 deaths (“Devastating Floods Hit Puerto Rico”, 2009).

Although average rain fall more than doubles during the hurricane season, Puerto Rico regularly experiences other significant rainfalls that are capable of causing floods. In 2008, San Juan reported 54.7 inches (138.9 cm) of rainfall, just 0.15 inches (0.38 cm) less than the year before (“2008 climate review for Puerto Rico”, 2009) and in the mountainous areas of the island they received 200 inches (508 cm) (Rivera, 2010). The heavy, year-round rainfall experienced by Puerto Rico is a constant cause of dangerous flooding.

There are two other factors that contribute to the danger of flooding in Puerto Rico. First, Puerto Rico is an island with multiple waterways. Puerto Rico has nearly 70 rivers and streams, originating in the central mountain range that are susceptible to flooding (“Floods and Droughts”, 1996). The numerous waterways, combined with the fact that during a hurricane all of its ports and bays are at risk, confirm that the entire island is susceptible to flooding. Another factor that increases flood risk in Puerto Rico is the topography of the island. Since the rivers and streams stem from the mountain range, the "stream valleys are narrow, relatively short, and [there are] steep-features that make the streams susceptible to flooding, particularly flash flooding" (“Floods and Droughts”, 1996). The Federal Emergency Management Agency (FEMA) reported in 2008, "[t]he torrential rainfall resulted in severe flooding of rivers, streams and roads, causing sinkholes, landslides, mudslides and structural collapses across the southern part of the island" (“Devastating Floods Hit Puerto Rico”, 2009). The frequency and dangerous nature of flooding in Puerto Rico poses a significant problem to the people living on the floodplains, and being able to determine population on a specific floodplain would facilitate the task of national agencies accessing emergency resources much more easily and more effectively.

2.3 U.S. Census

The United States Constitution mandates that a Census be taken every ten years in order to determine the population of states, cities, and electoral districts (Art. 1, Sect. 2). The government uses this information to assign seats to each state in the House of Representatives. The Census records demographic information including population, race, age, household size, and marital status. Individual statistics are not released for 72 years, but aggregate statistics are publicly available after they have been tabulated by the U.S. Census Bureau (“About us”, 2010).

Non-governmental groups such as insurance companies and businesses use the data to shape policy, reduce business risks, and analyze economic policies (“About us”, 2010). The U.S. Census Bureau publishes their findings in reports and ArcGIS maps. The ArcGIS maps are broken up into Census blocks which contain demographic information. This project makes use of both the Geographic divisions and the statistics available in these maps.

2.4 La Junta de Planificación

La Junta de Planificación, Puerto Rico’s planning board, is responsible for regulating flood-prone areas. As there are far too many people settled in hazardous regions for the government to easily relocate the entire population, La Junta de Planificación needs an accurate estimate of the population at risk in order to protect them. The Special Flood Areas Hazard Regulation Manual states that action is mandatory wherever flooding hazards provide dangers to the well-being of the citizens (Vargas et al., 2010). La Junta de Planificación identifies and removes illegal structures or fill that impedes water flow and is working with the U.S. Army Corps of Engineers (USACE) to complete projects to reduce flood risk such as the Rio Puerto Nuevo Flood Control Project. The Rio Puerto Nuevo Flood Control Project is an on-going project expanding channels and adding concrete and earth linings to the Rio Puerto Nuevo and its tributaries. Numerous other projects involve building or raising levees, creating walled channels, and improving existing channels along all rivers that flood ("Water resources development," 1998).   La Junta de Planificación needs more information about floodplain populations to continue cooperating with FEMA and the USACE to develop strategies to mitigate flood damage.

2.5 Local Flood Awareness

Flood awareness in Puerto Rico is important to this project because a significant part of the population is at risk to suffer from flood damage. Even though citizens of Puerto Rico reside in areas not suitably protected from heavy rain and floods, few are able to reduce their risk. Risa Palm and Michael Hodgson (1993) studied the strategies the residents of floodplains employed to reduce risk from flooding. Only approximately 5% of those surveyed had taken any steps to prevent flood damage, but the survey also indicated that those steps had been successful in mitigating flood damage. Subjects living in the most vulnerable structures, however, had not tried to reduce the risk of flood damage. They reported not protecting their homes from flooding because they are "powerless within the household" and due to the "lack of money to adopt the measures" to reduce the flood risk. Palm and Hodgson also found that the subjects were unwilling to move because they were partial to an area after having lived there for some time (Palm & Hodgson, 1993).

A study conducted in 2007 addresses the attitudes of settlers in floodplains in the flood prone areas of Lusaka, Zambia. Lusaka experiences flooding due to heavy rainfall and faulty dams. Economic factors in Zambia's history have forced poor people to live in these regions because of overcrowding in the cities. Many of the subjects reported settling in hazardous areas because "there was no other land available" (Nchito, 2007). They also indicated that poverty was the most common reason given for not being able to find safe land to build on and that they knew about the risks associated with flooding in the area (Nchito, 2007). This study confirms that settlers may risk the dangers of flooding when they cannot find elsewhere to live.

A study by Howard Kunreuther in 2006 further discusses resident attitudes on floodplains. Kunreuther notes that even though governments take action to reduce flood risk, it may not be adequate and sometimes creates a false sense of security for the people who live in these areas. He asserts that the residents are also partly responsible for their exposure to flooding, as they are "resistant to disasters and do not voluntarily adopt mitigation measures" (Kunreuther, 2006). Individuals in the risk area resist protecting themselves from the imminent danger presented by hurricanes and resulting floods. For residents without economic means, they may not be able to relocate or protect themselves, but residents with economic resources still resist moving if they feel their homes are comfortable.

Kunreuther also suggests a number of mitigation strategies for both low and high-income settlers. His first suggestion is to implement building codes such that any structures built in the vicinity of a floodplain must meet specific standards of structural integrity. He also suggests that those who take steps to protect themselves should receive tax incentives if their households meet certain benchmarks. Finally, he states that there must be a link between homeowners and insurance. If a homeowner owns property in an area that has high flood risk, they should be required to purchase insurance that appropriately "reflect[s] the risk of living in the area" (Kunreuther, 2006). These methods are extremely effective for people that can afford to pay for this insurance, but will likely be ineffective for settlers without the resources to purchase insurance.

An example from a 2007 study in Cape Town, South Africa demonstrated the effectiveness of appealing directly to residents of low-income settlements with instructions and recommendations for improving their houses' integrity. The authors created guidelines for the structures and suggested various methods for the city of Cape Town to provide information to those living in the region. They suggested pallets, concrete blocks, and stilts to increase structural resistance to flood damage as well as suggesting strategies for preventing the build-up of debris in drains and other water channels. They evaluated each suggestion's feasibility for residents without many resources. The authors also developed a method to determine flood risk for the city of Cape Town. They determined that small improvements could reduce the risk of death and property loss for settlements where monetary resources are scarce (Bouchard et al, 2007).

2.6 Flood Insurance

Flood insurance in the United States is provided by FEMA through the NFIP, although residents purchase their NFIP flood insurance policy from private insurers acting as agents for FEMA. Private insurers offer supplementary flood coverage, but adverse selection prevents them from providing basic flood coverage (Kron, 2009). Residents of high-risk regions buy flood coverage, but those living in low-risk regions do not. Hence, the cost to a company would need to be carried by relatively few customers and the premiums would be very high. As they can't set their premiums above those set by FEMA, the federal insurance policies are the only available coverage.

FEMA provides two types of flood insurance policies, content coverage and building coverage. Content coverage insures personal belongings, electronics, and small appliances, and building coverage insures against damage to the building, plumbing, electrical systems, and large appliances ("Summary of coverage", 2009). A claimant will receive a payment equal either to the Replacement Cost Value (RCV), the cost to replace the building, or the Actual Cash Value

(ACV), the value of the destroyed property. Content insurance always pays the ACV of the personal property damaged by flood (“Summary of coverage”, 2009).

FEMA requires residents in regions designated as high-risk, defined as a 1% or greater chance of flooding each year, to buy an insurance policy. The policy will change if FEMA decides that a property is a “severe repetitive loss property” and which meets one of two criteria: either four claims have been made on it of at least $5,000 or two claims have been made which total more than the value of the property (“Summary of coverage”, 2009). Owners of severe repetitive loss properties are required to relocate, elevate, or demolish their homes or they will be charged higher premiums or lose their coverage.

2.6.1 Flood Zone Designations

Insurance requirements and premiums are determined by location; residents of high risk areas pay higher premiums than residents at lower risk. FEMA separates floodplains into four categories: moderate to low flood risk, high flood risk, high coastal risk, and undetermined risk. Low flood risk areas are divided again into three more designations: “B”, “C”, and “X” (“Definitions”, 2010). “B” and shaded “X” regions indicate areas whose risk is between100-year and a 500-year. A 100-year risk means that there is a 1% chance of flooding within a one year period and a 500-year risk indicate regions that have a .2% chance of being flooded in a given year. “C” and unshaded “X” regions indicate areas of very low risk, less than a 500-year flood. Most inland floodplains in San Juan are designated “AE” or “X”. FEMA designated those coastal areas at risk of damage of flooding from waves in San Juan as “V” flood zones (“Definitions”, 2010).

Moderate to high risk areas are given a designation beginning with A which indicates a 100-year risk. The second letter indicates the status of the base flood elevation. An “AE” region’s base flood elevation is indicated on a FEMA flood map, “AH” regions indicate that shallow flooding results in a pond with an average depth of 1-3 feet (30-90 cm), “AO” indicates areas susceptible to sheet flow with an average depth of 1-3 feet from nearby streams or rivers, “AR” indicates areas at temporarily higher risk due to the construction of new water control systems, and “A99” indicates areas that are protected by flood control systems and do not have base flood elevations shown on the FIRM maps (“Definitions”, 2010).

Designations beginning with V indicate coastal regions susceptible to flooding from the ocean. These are shown with “V”, “VE”, and “V1”-“V30” which indicates the coastal area has a 1% chance or more of flooding each year and there is additional risk from strong waves. In contrast with “V” designations, “VE” and “V1”-“V30” zones base flood levels are shown on flood maps. Areas not analyzed by FEMA receive a “D” designation. This indicates that the area may be at risk of flood damage. FEMA may require residents of these areas to have flood insurance policies with premiums set by the uncertainty of the flood risk in the area (“Definitions”, 2010).

2.7 Geographic Information Systems

A Geographic Information System (GIS) is any system that stores and displays Geographic information. GIS differs from cartography as GIS refers to computer-based geodatabase software that records and analyzes spatial data in order to assess real world problems (Dempsey, 2008). GIS software is categorized into two primary data types used to display spatial data: geodatabase data and documentation data. Geodatabase data serves as the visual representation of the map and contains two types of data: vector and raster. Vector data is spatial data represented as points, lines, and polygons (Dempsey, 2008). Vector data represents a Geographic object with Cartesian coordinates. Raster data is data given by the group of individual cells that compose the entire map in GIS software. Any raster cell, which is similar to a pixel in a digital image, can contain values ranging from discrete data such as land-use and soil data, or continuous data like temperature, elevation, satellite images, and aerial photos (Dempsey, 2000). Data represented in multiple formats, such as rainfall totals, can be stored as either a raster or a vector.

Documentation data, also known as metadata, are text files that contain content quality, creation, and spatial information about a dataset, while a dataset contains information that describes the geodatabase file. Most GIS software uses another program to automatically manage this data. Common data stored by GIS involves title, publisher, spatial content, data theme, and content type. This project uses ArcGIS, a popular GIS program developed by the Environmental Systems Research Institute (ESRI). ArcGIS makes use of ArcCatalog to organize collected data for the ArcGIS metadata service, called ArcIMS. Metadata makes spatial information more useful by making it easier to locate and document datasets (Dempsey, 2000).

2.7.1 ArcGIS

ArcGIS, like other GIS software, is used to record, analyze, and display spatial data. ArcGIS is used in a variety of fields such as archeology, animation, urban planning, environmental impact assessment, logistics, and geographic history. This project used ArcGIS's ability to display spatial data for use in the creation of a population map. Multiple case studies helped illustrate how to use this spatial data.

Until recently, there was no mapping or record of the Baltic Sea, located just south of Finland and which borders many European countries. Rain that falls in the drainage basin around the Baltic Sea eventually flows into the sea itself. The Baltic Sea's drainage basin contains many distinct geological regions. In 1996, a group of scientists from universities including the Royal Swedish Academy of Sciences and Stockholm University created a GIS database encompassing the drainage basin. By using multiple sets of map layers, which encompassed the varying geological regions, they were able to generate information on the landscape characteristics and population distribution in the drainage basin of the Baltic Sea (Sweitzer, Langaas, & Folke, 1996). From this ArcGIS database, they were able to determine nutrient outflow, nutrient retention, and population densities through statistical analysis of the GIS data.

The Census Bureau of the United States also uses ArcGIS to aid in the collection of U.S. population information and in the creation of media that makes this data more presentable. According to Tim Trainor, Chief of the Geography Division of the United States Census Bureau, ArcGIS "is enabling the Census Bureau to efficiently collect quality data about the nation's people and economy" (Mitchell, 2009). The Census Bureau also stated that ArcGIS is useful due to its capabilities such as collecting, tabulating, and disseminating statistical data (Mitchell, 2009).

2.7.2 Hazus-MH

Hazards U.S. Multi-Hazard, commonly known as Hazus-MH, is an extension for ArcGIS developed by FEMA used to monitor and predict potential losses and impacts from natural disasters such as floods, hurricanes, and earthquakes ("Hazus Home", 2009). The potential losses considered in Hazus-MH include physical damage, economic loss, and social impacts. Physical damage refers to damage sustained by residential and commercial buildings, schools, and infrastructure. Economic loss takes into account lost jobs, business delays, and repair and construction costs. Social impacts include the effects of displaced households, and estimates of the cost for relocating and housing the individuals exposed to the disaster (“Hazus Home”, 2009). Hazus-MH is typically used to devise mitigation and recovery plans and to improve the preparedness and response of a community. Hazus-MH is an essential tool for all levels of government for making decisions regarding mitigation and emergency strategies in the face of natural disasters.

In 2005, researchers using Hazus-MH and ArcGIS software predicted the high water marks and storm surge heights that the victims of Hurricane Katrina witnessed. A high water mark refers to the mean height of the offshore waves of water that strike a coast during a hurricane, cyclone, or other tropical storm. The storm surge height is the maximum height of an offshore wave observed during a tropical storm. The night before Hurricane Katrina made landfall in the United States, Talbot Brooks, the director of the Center for Interdisciplinary Geospatial Information Technologies at Delta State University in Mississippi, used ArcGIS in association with Hazus-MH to determine the threat presented by the incoming hurricane. His ArcGIS predictions suggested that the Louisiana-Mississippi border would experience the highest storm surge ranging from 16 – 32ft (Talbot, 2005). The distance between the Louisiana border and Bay St. Louis, Mississippi is roughly 20 miles. A peak storm surge of about 29 feet was documented near Bay St. Louis, Mississippi after the hurricane, according to a study performed by USGS Mississippi Water Science Center (Turnipseed, Wilson, Stoker, & Tyler, 2007).

Hazus-MH and GIS software are powerful tools that are used to predict disasters and analyze risk and spatial or statistical data. One of the deliverables of this project is a population map of the studied floodplains. ArcGIS was used to organize and present the data collected and to make the layers that are combined into a population map by layering population and flood data over aerial photographs. FEMA and La Junta de Planificación will use these maps to plan mitigation strategies to reduce flood damages.

2.8 GPS

Global Positioning Systems (GPS) is a modern instrumentation system that identifies exact Geographic positions anywhere in the world. The GPS uses multiple satellites to triangulate the position of a receiver carried by a person or an object. The receiver measures the travel time of radio signals as they pass from satellite to GPS receiver. At least three satellites (four are preferred) are needed to give a three-dimensional position in free space, giving a longitude and latitude reading as well as an altitude ("Global positioning system", 2010). Most modern GPS receivers, such as the Trimble Juno SB, can give readings that are accurate to within three meters, although accuracy depends on the number of satellites engaged in the calculation. GPS's have many positioning, tracking, and mapping applications. GPS devices mark the specific location of a person or an object. GPS also allows routes to be plotted, followed, and logged; viewing the path of travel on land or in the air becomes simple. In mapping, coordinates are saved in a database and then imported into GIS software that then enables the points to be plotted onto a base map layer. These coordinates can be labeled to indicate the feature at that location. Qualitative surveying makes use of GPS as surveyed areas can be cordoned by GPS data so documentation of results from a specific area can be logged appropriately ("Global positioning system", 2010). Specific areas surveyed can be logged by line or point data by the GPS.

It is necessary to select the correct datum and coordinate systems in order to obtain accurate data. A datum is defined by the "ellipsoid used to represent the earth, and the point on the earth that is used as the origin of the datum" ("Getting Started Guide", 2010). Because the Earth is not a perfect sphere, datums are required to fit different regions on the globe in order to ensure accuracy. The datums used in the United States are the North America Datums of 1927 and 1983, abbreviated NAD-27 and NAD-83 ("Getting Started Guide", 2010). There is one global datum, the WGS-84, designed to be accurate everywhere. GPS's store most data in WGS-84 and convert NAD-83 to WGS-84 with only a change of about one meter. Coordinate systems are "reference frame[s] used to describe the location of objects within a spatial reference frame, or datum" ("Getting Started Guide", 2010). The two common types of coordinate systems are angular and Cartesian. Angular coordinates use latitude and longitude to specify a location while Cartesian coordinates use rectangular coordinates. For land-based data collection and plotting, GPS's use Cartesian coordinates expressed in meters or feet ("Getting Started Guide", 2010). A good example of this system is the United States Plane Grids. In this system, positions are given in terms of distance along the x- and y-axis in meters. The correct coordinate system within the correct datum for the region are required to ensure accuracy when plotting points and importing them into a GIS.

2.9 SPSS

The Statistical Package for the Social Sciences (SPSS) is a program for statistical analysis. SPSS was developed by Stanford University graduate students Norman H. Nie, C. Hadlai Hull and Dale H. Brent in 1968. It was designed to allow them to analyze information gathered for the social sciences ("Spss, inc. corporate," 2010). SPSS quickly became popular in universities throughout the United States because of its portability and even the National Aerospace and Space Administration (NASA) and National Forestry service began to use SPSS for statistical analysis ("Spss, inc. corporate," 2010).

SPSS allows users to input and analyze nominal, ordinal, and scale data in the form of variables. Nominal data lacks categorical hierarchy; an example of nominal data is marital status. Ordinal data has clearly ordered categories but the distance between categories is undefined, such as heavy and light. Scale data is also known as quantitative or continuous data is measured on an interval scale and includes any numerical information like income or population (SPSS). SPSS can create frequency charts which describe both the number and percentage of cases with any given characteristic. It also allows the user to build charts which graphically display relationships between any two variables (SPSS).

SPSS was used to analyze the data collected from a survey conducted about flood insurance, flood awareness, and flood mitigation strategies and to display the relationships between variables. The analysis connects information about flood insurance and flood awareness with community and demographic data. Conclusions drawn from the SPSS analysis will help La Junta de Planificación to create strategies to mitigate flood damages and help residents protect themselves from floods.

2.10 Summary

This chapter presents the reasons people live in areas where they face serious flooding, discusses flooding and the organizations that attempt to mitigate flood damage, examines the steps that people take to protect themselves, physically and with insurance, and reviews computer programs that will be useful tools throughout this investigation. In general, floodplain residents do not have the resources to relocate or protect themselves adequately from a severe flooding event. Historical and socio-economic factors have forced them to live in these high-risk regions. FEMA and La Junta de Planificación hope to minimize the risks, but they do not have complete current information on the population on the San Juan floodplains. This research fills this gap in knowledge by making ArcGIS maps of floodplains that governmental organizations can use to estimate population. The methodology created by the team will serve as a template for future efforts to estimate population in floodplains around Puerto Rico. The project also provides FEMA and La Junta de Planificación with information regarding the strategies used by floodplain residents with respect to their flood insurance.

CHAPTER 3: METHODS

The main goal of this project was to estimate the population and population density on the floodplains in the Municipality of San Juan and to document this methodology for use in other municipalities throughout Puerto Rico. Other objectives included creating population and population density maps and surveying floodplain residents about their experiences with flooding and damage mitigation. Upon arrival in San Juan, the team met with Wilfredo Más from the Flood Zone Administration office of La Junta de Planificación and Dr. Angel David Cruz of the University of Puerto Rico (UPR) to finalize our deliverables. The first deliverable is an estimation of the population living on floodplains in San Juan, which takes the form of a map using ArcGIS software. This required knowledge of ArcGIS 9.2 and map data from several sources including the U.S. Census Bureau, La Junta de Planificación, and the UPR Department of Geography. The second deliverable is results and conclusions drawn from a stratified-sample survey in five of the largest flood areas in San Juan. Figure 2 is a Gantt chart showing approximately when our group approached each aspect of the project.

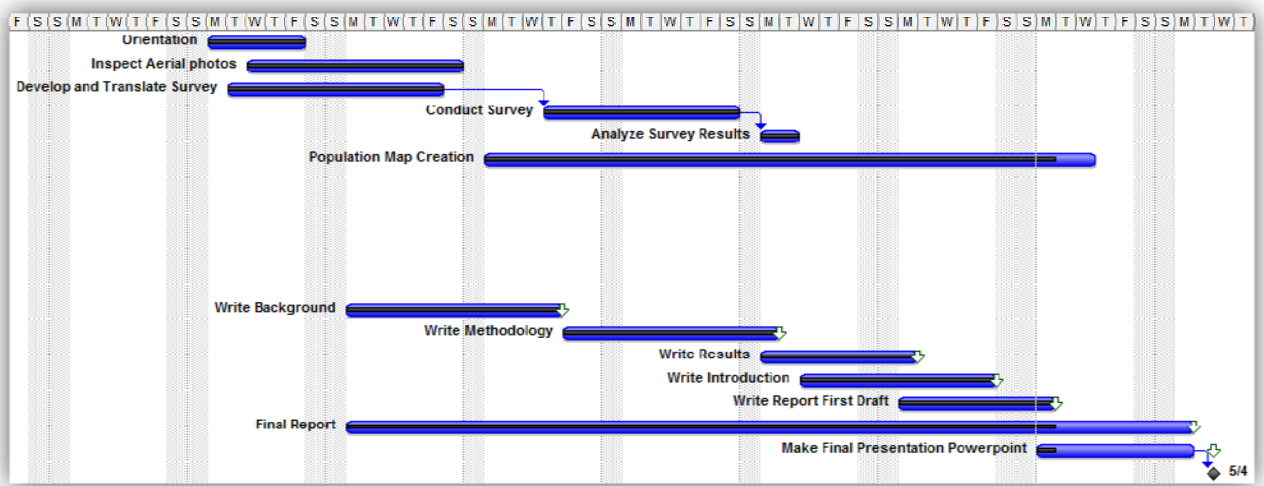

Figure 2: Project Timeline

3.1 Data Collection

In order to estimate the population residing on floodplains in San Juan, the first step was to collect data necessary to produce a population map using ArcGIS. The team collected population data, flood zone boundaries, Census block boundaries, and aerial photographs. The team also developed and implemented a survey to collect information about flood insurance and the floods experienced by the residents of San Juan's floodplains.

3.1.1 Aerial Photographs and Floodplain Boundaries

The first step towards estimating the population living in floodplains in San Juan was to gather aerial photographs. With these photographs, the team was able to see all of San Juan at once and magnify any area to clearly see individual buildings. Dr. Angel David Cruz provided aerial photographs from a map database maintained by the Jacksonville District of the USACE. The photographs were then uploaded to ArcGIS and formed the base layer for every other map. Later in the project, the aerial photographs allowed the team to relate abstract objects such as Census block and floodplain boundaries with concrete landmarks such as roads, rivers, and buildings.

The next step was to find the floodplain boundaries in San Juan. Flood Insurance Rate Maps (FIRM) provided by FEMA were used. These maps show which areas are at risk of flooding and the risk level each that area faces. The team overlaid the floodplain regions over the San Juan aerial photographs using ArcGIS to determine which areas of San Juan are in the floodplains. In conjunction with the aerial photographs, these maps were used to determine which buildings were at risk of flood damage.

3.1.2 Census Block Boundaries and Population Data

The final layer added to the working map in ArcGIS was the 2000 Census data from a map database maintained by La Junta de Planificación. This map breaks San Juan up into Census blocks. Census blocks are polygons that contain information including number of households, population, and other demographic data. This Census data was downloaded and imported into ArcGIS. The team created another layer showing the Census blocks and overlaid that layer on top of the aerial photographs and floodplains. With the floodplain map and aerial photographs, the Census block data allowed us to estimate the population living in the floodplains.

3.1.3 Flood Insurance and Flood Damage Mitigation

The team obtained information about flood insurance, flood damage mitigation and the flood experiences of the people of Puerto Rico using an orally administered survey (Appendix A). The survey questions are grouped into three sections: general demographic information, information about the residence, and information about insurance, flooding, and damage mitigation. The community where the survey was given was also recorded. Grouping the questions facilitated discovering connections between factors such as age, home ownership, and number of floods experienced with insurance status and mitigation strategies. To make the survey quicker and more attractive to the subjects, a number of questions were not asked if they did not apply to the subject based on earlier answers.

Anonymity was one of the greatest survey concerns. Because flood insurance is mandated by law in the areas being surveyed, the surveyors made it clear to the subjects that the surveys were completely anonymous and voluntary and no identifying information was collected to minimize tainting the survey data with inaccurate responses. Although GPS points were also taken in the areas surveyed, they do not correspond to individual houses.

Surveys were administered in five different communities: Reparto Metropolitano, University Gardens, Puerto Nuevo, San José, and Barrio Obrero. Accoding to Dr. Cruz, these communities each represent a different mix of socio-economic and demographic characteristics and lie within floodplains. By choosing areas with different populations, the intent was to draw general conclusions about flood zone residents in San Juan and more specific conclusions about flood zone residents within each community. To sample the entire portion of the community within the floodplain, several smaller teams were created and each was assigned a small section of the community. Every small team had at least one student from the University of Puerto Rico (UPR) Department of Geography. Dr. Cruz and the team went to several classes to tell the students about the project and to ask for help. The UPR students assisted by administering the survey in Spanish, as only one member of the project team could speak enough Spanish to effectively administer the survey. Each team was given a map of the floodplain and their assigned area section. Figure 3 shows the areas that were surveyed. The yellow dots correspond to GPS points taken along streets that were surveyed.

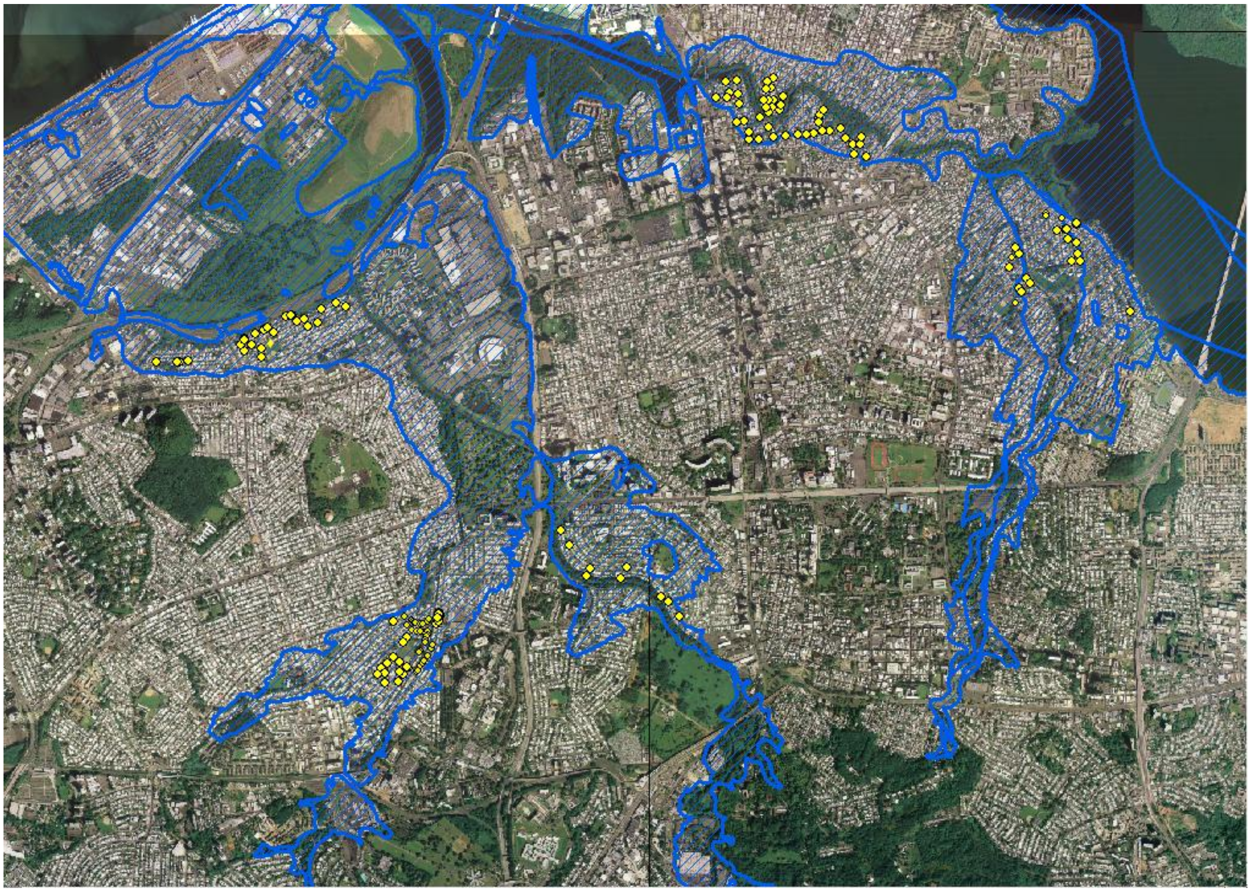

Figure 3: Areas Surveyed

The prescence of metal bars, fences, and walls in San Juan presented a barrier to administering a survey door-to-door as it was impossible to knock on doors. The team learned from the UPR students that the best way to contact the residents of a home is to stand near the wall or window and yell a greeting into the home. This strategy was successful and the majority of subjects were willing to participate in the survey.

To maximize the area covered within each section, each team attempted to survey every third residence on each street. If the residents were not home, did not answer the door, or were unwilling to take the survey, the surveying team moved on to the next house. This allowed for an even Geographic distribution of surveys in each community. A sample size of 385 was chosen in order to give a 5% confidence interval with 95% confidence, according to Equation 1.

$$n = \frac{Z^2 p(1-p)}{E^2} \qquad (1)$$

n is the number of surveys required to have a confidence level associated with the standard value Z, the chance of a certain response p, and error E. The standard value for 95% is 1.96, the chance of a particular response is 0.5, and the error is 5%. 418 surveys were collected, resulting in a slightly higher confidence.

3.2 Population Estimation

Using the aerial photographs, floodplain boundaries, Census block boundaries, and data from the 2000 Census in conjunction with ArcGIS software, our team estimated the number of residents that live on floodplains in the Municipality of San Juan. The floodplains in the municipality of San Juan belong to five types of flood regions: AE, AO, VE, Floodways, and 0.2 percent annual chance floodplains. After determining the populations of each of the five types of flood regions separately, summing the AE, AO, VE, and 0.2 percent annual chance floodplains yielded the population estimate for all floodplains in San Juan. The floodway population estimate was not included because the floodway refers to an area already within another floodplain and the population in these areas is already included in the estimate. Although the floodway population is not necessary to determine total floodplain population, the team calculated this population because the residents of these regions face a more serious flood risk. Figure 4 shows an example of a floodway entirely within an AE floodplain and its population was therefore not counted in the total.

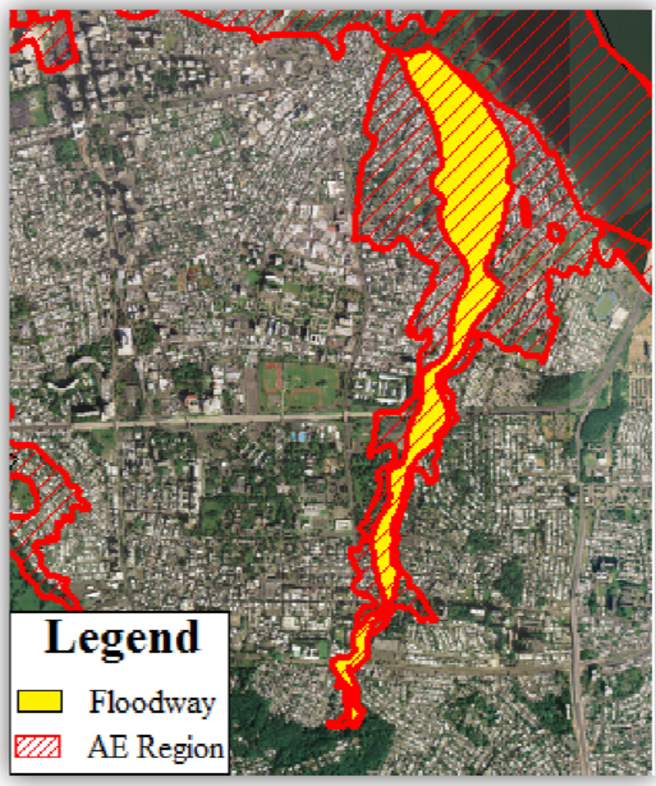

Figure 4: A Floodway within a Floodplain

The next step was identifying which Census blocks are inside the floodplains. To find the Census blocks within floodplains, ArcGIS was used to create layers with the Census blocks outlined by each of the floodplains. To create each of these layers the *Clip* tool found in the Arc Toolbox in ArcGIS was used. In order to create a layer of Census blocks within a specific floodplain, the team first selected a zone to be the outline of the floodplain. This was accomplished by clicking *Selection*, and then choosing *Select by Attribute*. Figure 5 shows the resulting window.

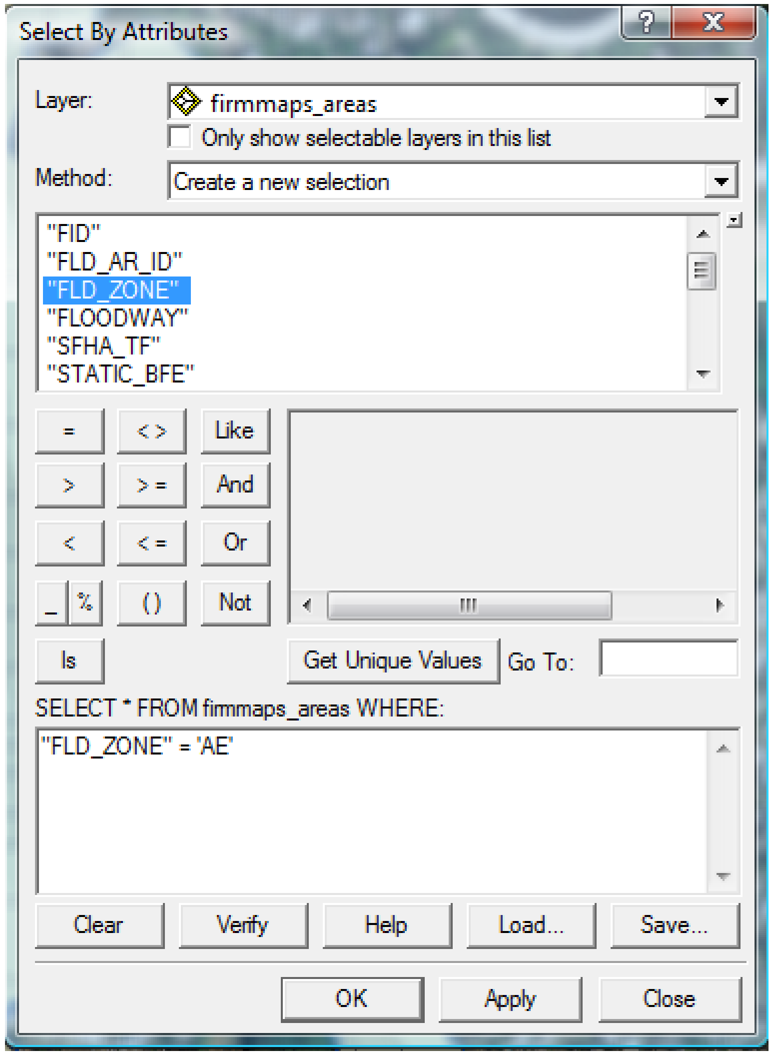

Figure 5: Feature Selection

The firm map data was selected under the layers option, and then the flood zone data was selected. In the *Get Unique Values* menu, the specific zone was chosen (in Figure 5 it is the AE zone). The equation in the window then read “FLD_ZONE”=’AE.’ This process created a new layer for the selected floodplain, named “Firm Map Floodplain”. With this layer it was possible to create a layer consisting of the Census blocks outlined by each of the floodplains using the Clip tool displayed in Figure 6.

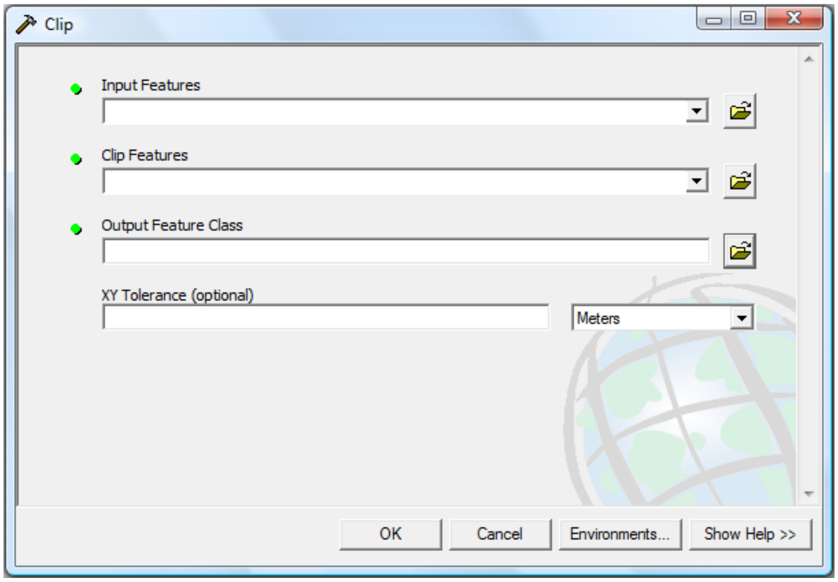

Figure 6: ArcGIS Clip Feature Menu

The team chose “Census blocks” as the input feature and the “Firm Map Floodplain” layer as the clip feature. A layer was created that allowed visualization of the floodplains and the population inside them. This layer was named “PRBlocksAE” by altering the desired file name in the *Output Feature Class*. More importantly for estimating the population, the automatically generated attribute table associated with the layer provides a list of all the Census blocks within the flood region. The Census blocks were then clipped by each floodplain designation to produce a map layer that contained only the blocks that overlapped those floodplains.

Next, an Excel spreadsheet was created using the Census blocks information from the attribute table. The team copied the columns labeled ID (the Block ID) and POP2000 (the population of each block). The team then created columns for the number of buildings in the Census block and in the floodplain, then buildings in the Census block but not in the floodplain, and the estimated population living in both the Census block and the floodplain. The columns of Table 1 show the columns in our spreadsheet with a description of the source of the information in that column.

ID	POP2000	Buildings Included	Buildings Excluded	Estimated Population
Given from Attribute table.	Given from Attribute table.	Found by counting buildings in aerial photos	Found by counting buildings in aerial photos	Equation 3

Table 1: Population Calculator Spreadsheet

The next step in creating a population estimate was filling the empty columns in the spreadsheet. The column detailing the average household size was calculated by dividing the population of the block by the number of households. The team used the unclipped Census block and floodplain layers over the aerial photos to fill in the columns with the number of buildings in the Census block included and excluded from the floodplain. Figure 7 is an example of a section of the resulting map. The floodplain is shaded with a blue hatch so the aerial photo can still be seen, and the Census blocks are outlined in red.

Figure 7: Census Blocks near a Floodplain

Before counting, a set of rules was established, dictating how buildings were counted. If part of a building was in the floodplain then the entire building was considered to be within the floodplain because FEMA requires all buildings that are partially in a floodplain to have flood insurance. The team also decided that it was unnecessary to count the buildings in a Census block completely in or out of a floodplain. For adjusting the population of the Census block, only the ratio given in Equation 2 is important:

$$\frac{BUILDINGS\ INCLUDED}{BUILDINGS\ INCLUDED + BUILDINGS\ EXCLUDED} \tag{2}$$

If every building in the Census block is in the floodplain, Equation 2 is equal to one. Block 1 in Figure 7 is an example of a Census block with all buildings in the floodplain. For this block, the team inserted a one in the buildings included column and a zero in the buildings excluded column. If the floodplain area in a Census block does not include any buildings, the ratio detailed in Equation 1 is set to zero. Block 2 in Figure 7 is an example of a Census block with no buildings in the floodplain. In this case, a zero was entered into the buildings included column and a one in the buildings excluded column.

If the floodplain area in a Census block includes houses in the flood region and houses that are outside the flood region, the team estimated the population using the ratio in Equation 1. The team counted the buildings inside the floodplain, and the buildings outside the floodplain. Block 3 in Figure 7 contains 17 buildings within the floodplain and 4 buildings outside the floodplain. In this case, Equation 2 is equal to 17/21, approximately 0.810. The team used this ratio to determine the estimated population column. To determine the estimated population of a Census block, Equation 3 was used.

$$\frac{2000POP * BUILDINGS\ INCLUDED}{BUILDINGS\ INCLUDED + BUILDINGS\ EXCLUDED} \tag{3}$$

Table 2 below gives an example where data that was collected was entered into the Population Calculator Spreadsheet. It demonstrates how to determine the estimated population in the three different cases; when no buildings in the block are in the floodplain, when a portion of the buildings in the block are in the floodplain, and when all of the buildings in the block are in the floodplain.

ID	POP2000	Buildings Included	Buildings Excluded	Estimated Population
160	22	0	1	0
285	32	4	10	9
289	106	1	0	106

Table 2: Example of Population Calculator Spreadsheet

After the population for all of the Census blocks was estimated within the floodplain region, the team estimated the population of that floodplain region. The population estimate is the sum of all estimated Census block populations. This process was repeated for each flood risk designation, resulting in a total population estimate for floodplains in the Municipality of San Juan.

3.3 Population Map

After determining the estimated population for the Census blocks partially inside the floodplains, a population map of the flood risk regions was created. In ArcGIS, seven files are needed to create a population map. Six of the files used for each of the flood risk regions' estimated population were already available in their final form: the project file (.PRJ), the .SBN file, .SBX file, the .SHP file, the XML file, and the .SHX file. These files give ArcGIS the information it needs to correctly display and orient the layer. The seventh file needed is the OpenDocument Spreadsheet, which contains all of the raster data except the aerial photographs. An OpenDocument Spreadsheet file associated with each flood risk region map already existed, but they contained the unadjusted 2000 Census population. This information was indicated by "POP2000" in the spreadsheet. In order to create a new OpenDocument Spreadsheet with estimated populations, the spreadsheet was opened for each floodplain region and the estimated population was inserted from our population calculator Excel spreadsheet.

Once the spreadsheet was updated, the next step was to create the population map. Within ArcGIS, the team configured each map to display the estimated population using the newly created spreadsheets. To change the information displayed by the map, the layer properties menu of each flood region map was opened and estimated population was chosen under the symbology tab. Our team experimented with the available methods for grouping the data in ArcGIS. By accessing the classification pull down menu in the symbology tab, it is possible to group the data using the following methods: Manual, Equal Intervals, Defined Interval, Quantile, Natural Breaks (Jenks), Geometric Interval, and Standard Deviation. Using the Natural Breaks method, the classes, or groups, are defined by natural breaks found within the data. The boundaries for these intervals are set where jumps in data values exist (Environmental Systems Research Institute, 2007). Since the population data had no preset intervals nor did it relate to a geometric series, the team decided to use the natural breaks in the data to determine the class boundaries. Our group used a graduated color ramp to display the data, shown in Figure 8 below.

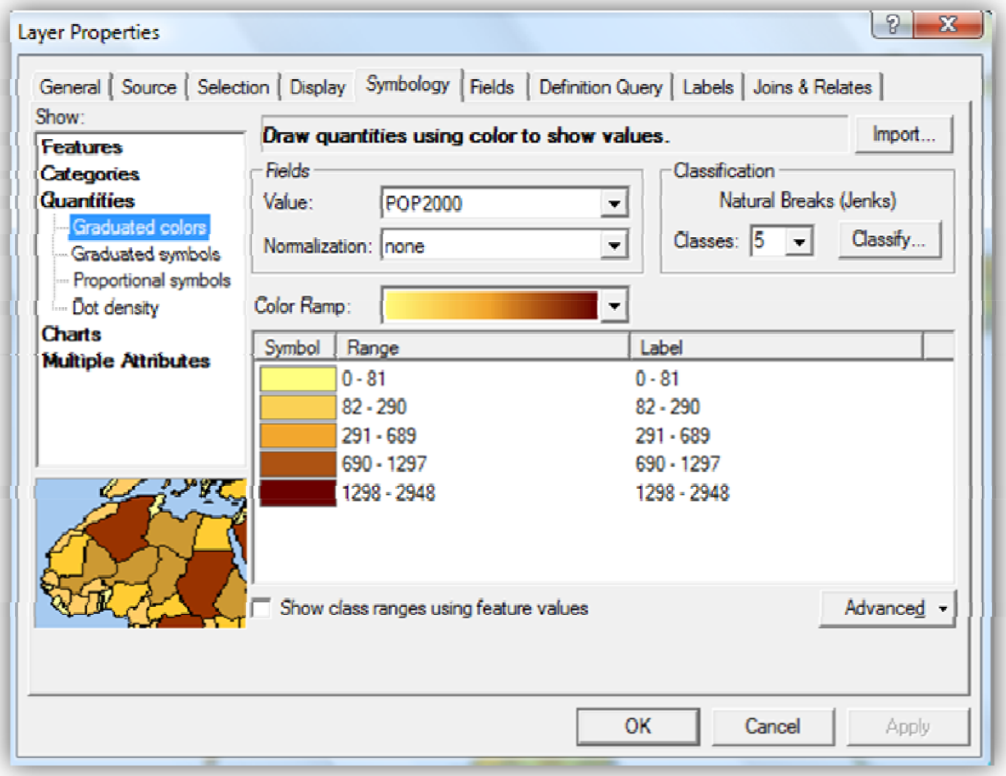

Figure 8: Layer Property Menu

To display the differences in population throughout the map the team chose seven shades. Each color represents a range of population values automatically produced by the Natural Breaks method. Our team used a color ramp ranging from light tan to dark brown to display the population data. Identical color scales were chosen for each floodplain so that the information displayed would be consistent across the entire map. The completed population map of each floodplain is displayed in Figure 9.

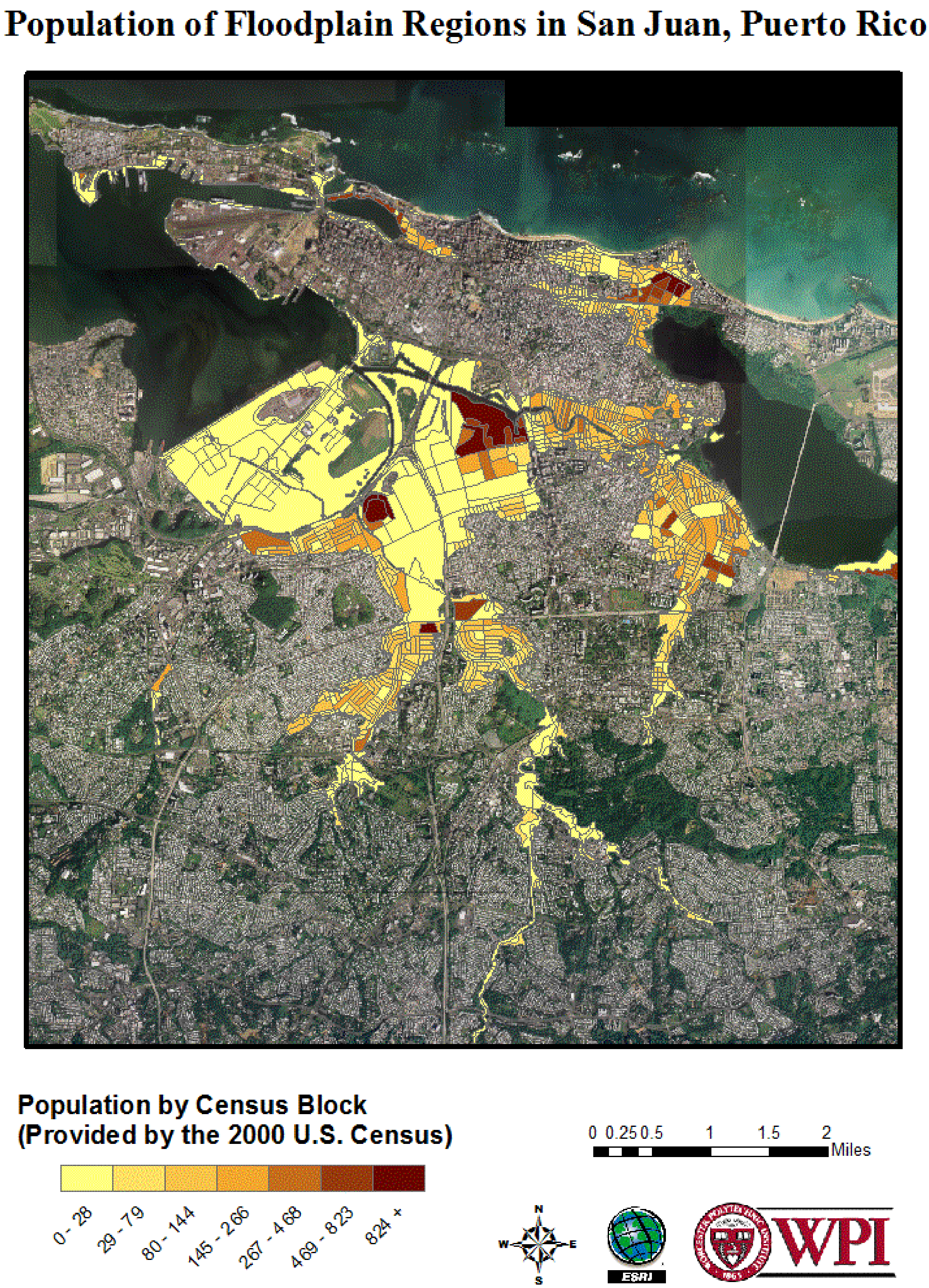

Figure 9: San Juan Floodplain Population Map

To calculate the population of any arbitrary floodplain or section of floodplain, ArcGIS can select any number of population blocks and calculate the sum of the individual populations in the selected area. The *Select Features* and *Statistics* tools are used to select a specific region and then calculate the population of the selected region. The *Select Features* tool and selected floodplain are circled in Figure 10. The *Statisics* tool is accessible through the *Selection* pull down menu, shown in Figure 11. The *Selection Statistics* menu is also displayed in Figure 11, showing the estimated population of the selected region circled in Figure 10.

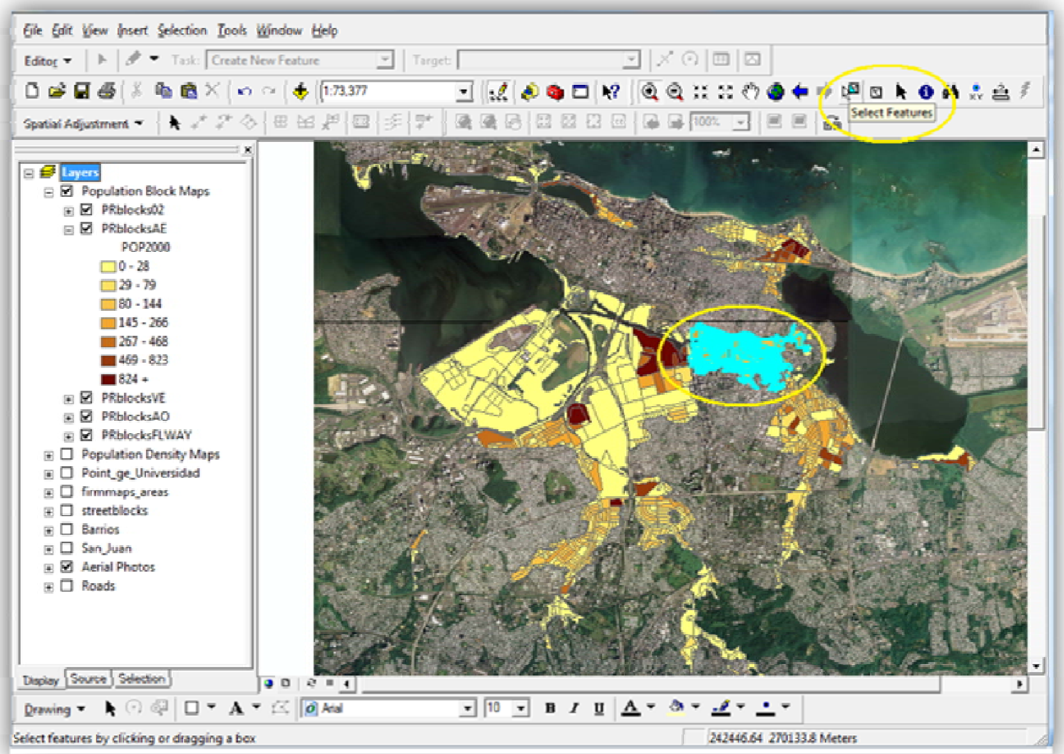

Figure 10: Select Features Utility

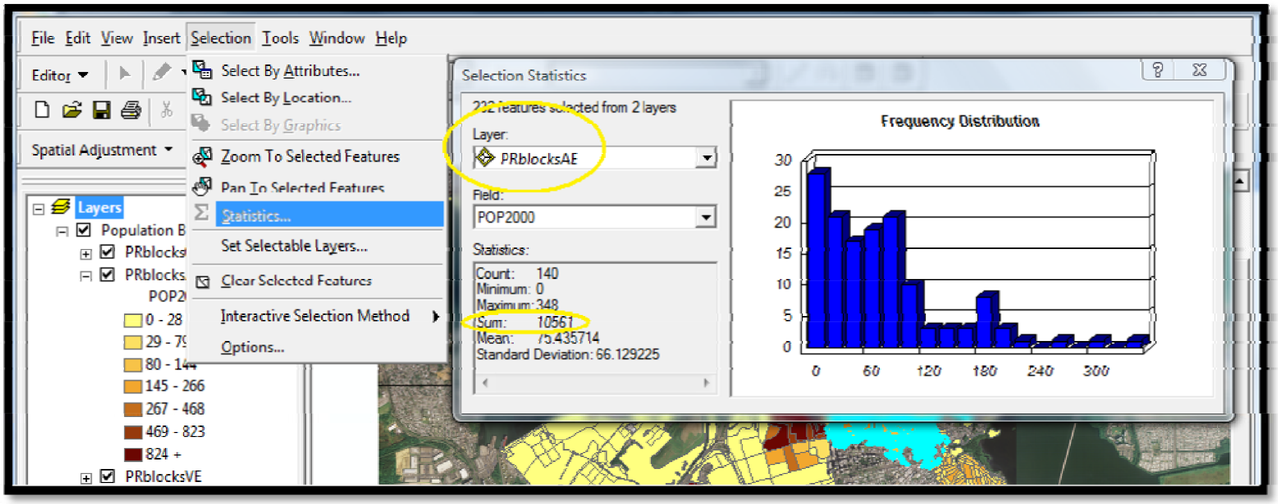

Figure 11: Statistics Utility and Selection Statistics Menu

3.4 Population Density Map

A population density map differs from a population map in that a density map shows the number of people per unit area. These maps are useful for risk assessment and evacuation procedures during emergencies because they allow resources to be allocated more efficiently. Population density is the ratio of population and area. To find the density of Census blocks, the population was divided by the area of that block, as in Equation 4.

$$Population\ Density = \frac{Population\ in\ Census\ block}{Area\ of\ Census\ Block} \tag{4}$$

The population in each Census block determined in section 3.2 was entered into a new Excel spreadsheet. The team used the *measure* tool in ArcGIS to find the area of the Census blocks. With the measure feature (circled in blue in Figure 12), the area of each Census block was measured. The area was then entered into the Excel spreadsheet. The population was then divided by this area to produce the density for each Census block. This procedure was repeated for each Census block in each flood region in San Juan.

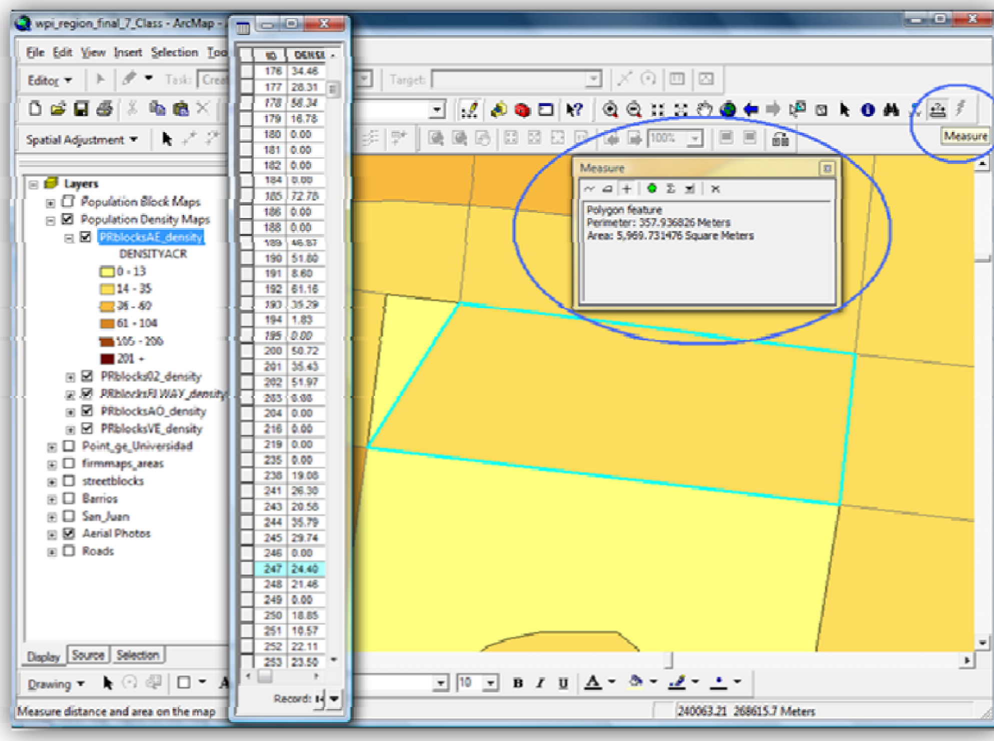

Figure 12: Measure Tool and Population Density

When the densities had been calculated the team inserted the density values of each Census block into the OpenOffice Spreadsheet that corresponds to each floodplain region. To do this the team created a new column for the density in the OpenOffice Spreadsheets containing each layer's metadata. The density was inserted into this column. The metadata for each block now contained the population density. The team then created a map showing population density.

Generally, population density maps are of large areas such as countries and states encompassing many fields, forests, farmlands, and small towns and villages and they have lower population densities than those calculated within the floodplains. The map created by the team is of a relatively small area, and this area is completely inside a high-density metropolitan area. Due to these factors, the densities of this project's floodplains are much higher than the densities of a country, state, or even another city's population density map. Thus, the conventional ranges of density did not apply well to this project. The group decided to use the Natural Breaks (Jenkins) classification method for classifying population density since it finds the natural breaks that occur within a data set and defines the boundaries using these breaks (Environmental Systems Research Institute, 2007). The team chose to display population density with persons per acre as the unit of measure. An acre is closer to the size of an individual Census block than a square mile or kilometer; therefore, the density more accurately represents the density of the Census block. Another concern was the number of colors used. The team chose six classes of colors so that they would remain easily distinguishable while having them increase in darkness from beige to dark brown to indicate increasing population density. Finally, each floodplain region was set to display identical colors and class ranges.

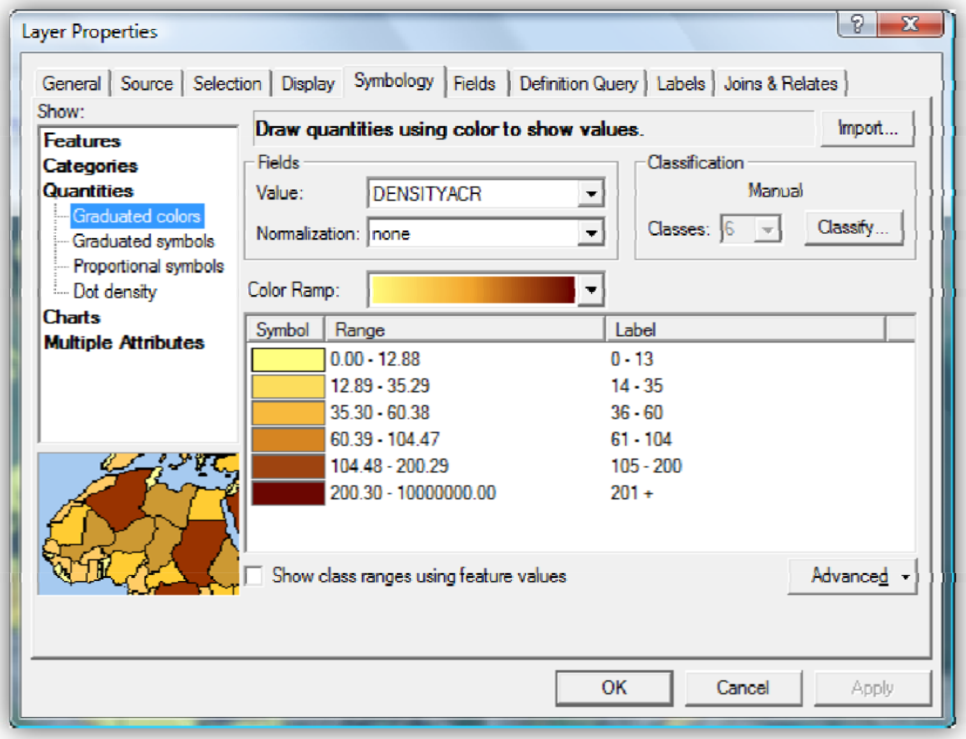

Figure 13: Population Density Layer Properties

3.5 Survey Analysis

The survey data collected from the survey was entered into SPSS to find connections between demographics, housing, flood experience, flood insurance, and flood damage mitigation. SPSS was used to analyze the data because of its ability to easily cross-tabulate data and produce graphs and charts better suited for social science applications. With SPSS, charts and tables were created to clearly demonstrate the frequency of cases involving one or more variables. Many different relationships were examined, with special attention given to differences between communities; charts created using SPSS divided the survey data into sets according to community which made comparison much simpler.

CHAPTER 4: RESULTS AND DISCUSSION

La Junta de Planificación and Dr. Cruz requested the following deliverables: population and population density maps, a tutorial for estimating floodplain population, survey data on floodplain awareness, flood insurance, and flood damage mitigation. This chapter discusses the maps and possible applications, the floodplain population estimation tutorial, and the conclusions drawn from the survey data.

4.1 Population and Population Density Maps (Appendices C and D)

In this project, a population map (Appendix C: Population Map) is used to display the population of the floodplains in the municipality of San Juan. The number of people living in each Census block can be found with the population map using the legend and color of the Census block. In ArcGIS, it is possible to find a closer estimate of the number of people living in that block and to select an area and estimate the population that lives in a floodplain in that area. An estimate for the total floodplain population in San Juan can be found using a similar process. In turn, this estimate can be used to determine resource need to be allocation to mitigate flood damage and prevent loss of life. Figure 14 shows the population residing within the floodplain for each Census block of Barrio Obrero using colors to illustrate the distribution of population.

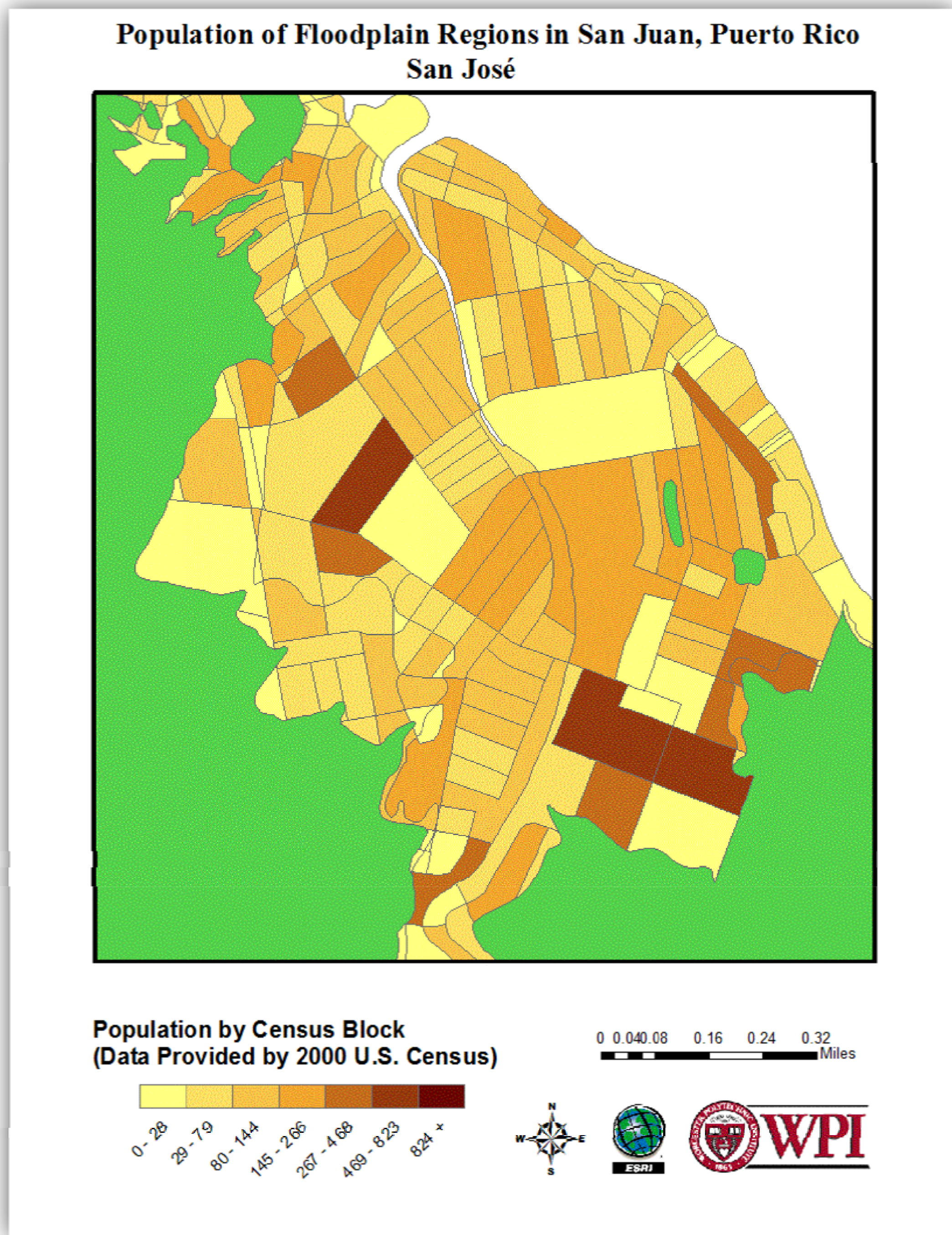

Figure 14: Population Map of San José

While a population map is useful for finding the population of an area, a population density map (Appendix D: Population Density Map) is a better tool for deciding how and where to allocate emergency resources because it shows the number of people per unit area. Resources can be allocated more efficiently to more densely populated areas. In ArcGIS, the population density of a Census block can be determined, as well as an average population density for a specific floodplain or all floodplains in San Juan. Figure 15 displays the density of the population residing in the floodplains of San José. The units are in persons per acre and the data was provided by the 2000 U.S. Census. The darker areas depict the higher densities; from this we can determine that the population is very dense in the north-west and south-east areas. These areas require more resources to properly prepare for any flood hazards. From these maps, the team estimated the total population living in each flood zone designation in San Juan. This estimation is in Table 3.

Region	Population
AO	36
VE	195
Floodway	4944
0.2% Chance Floodplain	18716
AE	65964

Table 3: Floodplain Population by Region

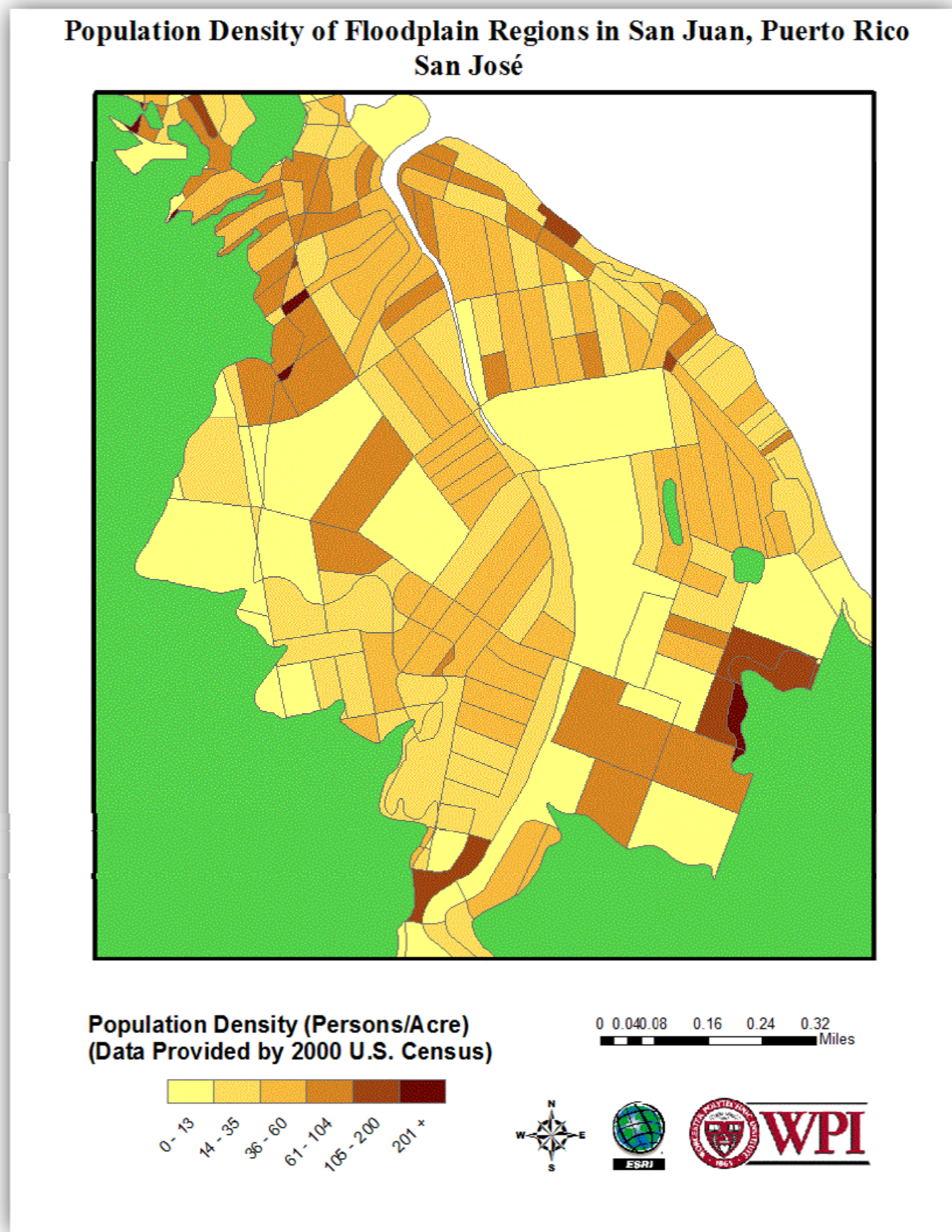

Figure 15: Population Density Map of San José

4.2 The Population Estimation Tutorial (Appendix E)

One goal of this project was to create a methodology for estimating population in a floodplain region. The entire process was documented beginning with the acquisition and input of data into ArcGIS and ending with the creation of a population map, a density map, and population estimation. The team used this process to create a tutorial which is a step-by-step guide for estimating the population of the floodplains in a region. The tutorial describes obtaining necessary data; including Census block data, FIRM maps, and aerial photographs. The next section details how to upload the data and prepare it for the estimation process. The tutorial then explains the process for estimating the population of a floodplain. Finally, the process for creating population and population density maps is described. The team felt that a tutorial is the most effective way of conveying our methodology for use by other groups. The step-by-step approach will reduce the amount of background in ArcGIS and other software required to estimate the population of an area.

4.3 Completed Survey Results (Appendices F, G, H, I, J, and K)

Over the course of four days, 418 surveys were collected from five different communities in the municipality of San Juan, representing a full spectrum of socio-economic statuses. The subjects represent the entire population of floodplains in San Juan as the proportion of surveys from each community is approximately equal to the proportion of that community's population to the total population. The surveys also come from areas that are Geographicly diverse within the communities. As much as possible, surveys were taken on every street in each community. The survey was administered both during the week and on the weekend in order to reach a more diverse group of people.

The first section of the survey dealt with demographic information. The majority of subjects (83.5%) are older than 36 years of age, and more than half (56.2%) of those surveyed are female. It was expected that those surveyed would generally be older; no new homes have been built in these areas since legislation was passed prohibiting construction on floodplains and from research, the team expected that the residents in these communities would tend to stay in the same home for their entire lives. This expectation is supported by the data graphed in Figure 17. A majority of people own their own homes (63.2%) and have lived in their homes for over 16 years (56.2%). A number of subjects stated that they had lived in their homes for their entire lives. Another 19.4% live in the same building with the owner of the home; often the owner of the building or residence is the subject's mother or father.

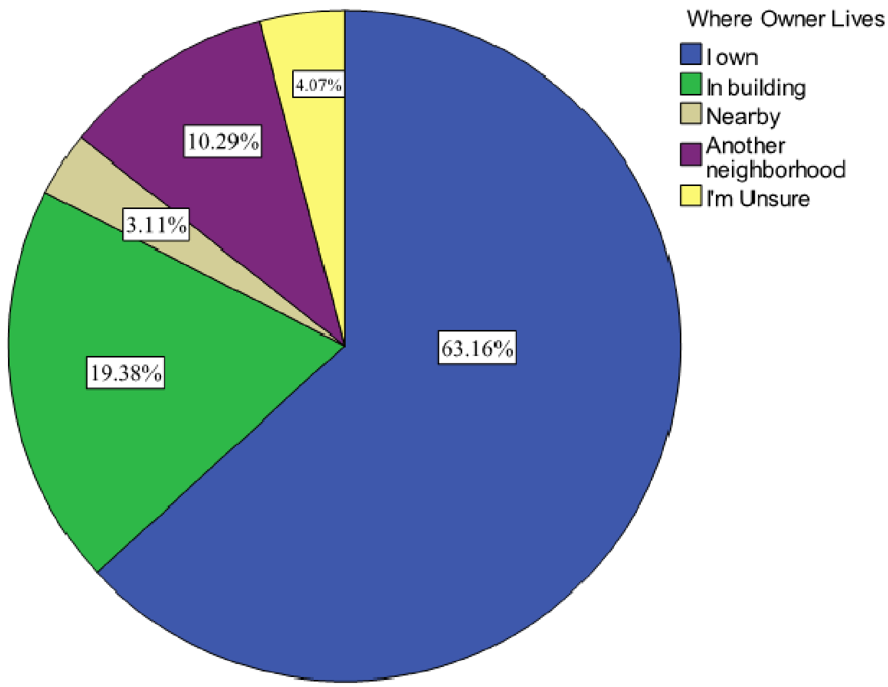

Figure 16: Residence Ownership

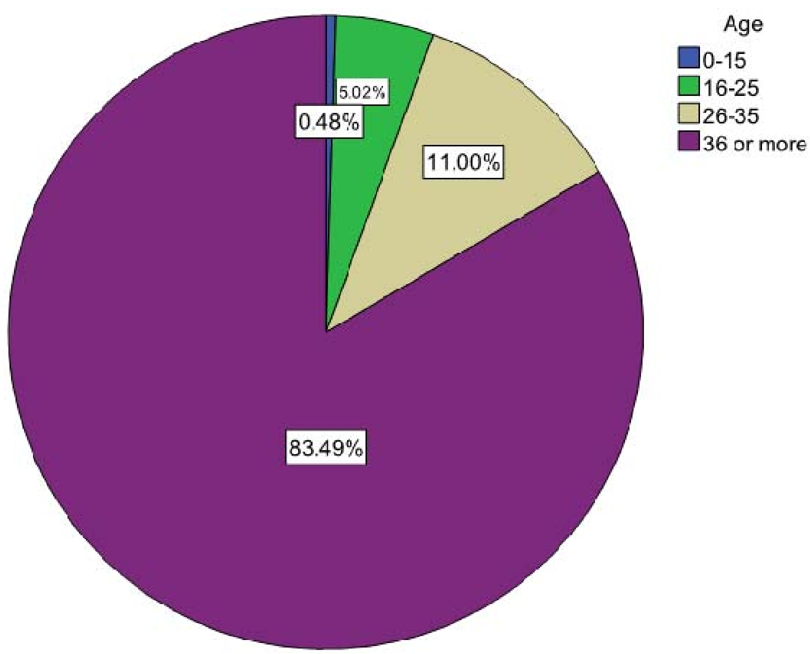

Figure 17: Age of Survey Subjects

The next section of the survey dealt with the construction of the housing. Most houses (90.9%) of those surveyed are constructed completely out of cement, which is less susceptible to flood damage than wood. The only houses with both wood foundations and wood walls are in the two poorest communities, Barrio Obrero and San José. The team noticed that in many areas, the houses are raised, as in Figure 18, in order to prevent flood damage.

Figure 18: A Raised Home with Raised Carport

The third section of the survey asked subjects about their knowledge of their community's designation as a floodplain and what they believed caused the flooding in their neighborhood. Just over three-quarters (77.0%) responded that they are aware that the area they live in had been declared a floodplain by FEMA. While 23.0% of subjects are not aware they live in a floodplain, only 5.0% responded that it does not flood in their neighborhood. Drainage problems were identified as a cause of flooding; 44.2% of subjects indicated that a lack of drainage was causing flooding. This question often led to comments that the government was at fault for not keeping the drains and canals meant to drain floodwater clear of garbage. Others blame nearby construction for the flooding. In Barrio Obrero, some of the subjects responded that a nearby highway bridge had increased the amount of garbage going into a lagoon bordering the community. This extra garbage caused the lagoon to overflow its banks into the streets. In

Puerto Nuevo, the construction of a highway had created a pond next to the community, shown in Figure 19. This pond had been part of the river, but the pipes that connected the two were chronically clogged with garbage and plant material resulting in poor drainage. The municipal government built a pump station to pump excess water from the pond back into the river, but in

Figure 19: Pond near Puerto Nuevo

November, 2009 the pump station did not operate properly and a number of homes were flooded. The canals built to reduce flooding are also blamed in some areas, especially in Reparto Metropolitano, where the canal walls are bending in towards the canal, and the subjects are unhappy with the government's effort to protect them from flooding.

Although flood insurance is required by the federal government for people living in floodplains, only 28.9% of those surveyed responded that they have flood insurance, while 54.8% responded that they do not have flood insurance and 16.3% were unsure. In general, people who have experienced more floods and more instances of flood damage have flood insurance more often than by those who have not experienced floods or flood damage. The strongest predictor of a subject having flood insurance is his or her community. In Figure 20, the difference between communities is clear; although the percentage of respondents who are not sure if they had flood insurance or not is relatively constant regardless of community, ranging from 14.1% in San José to 23.2% in Reparto Metropolitano, residents in the wealthier communities are far more likely to have flood insurance than those in less wealthy communities. Very few residents of the two poorest communities, San José (21.5%) and Barrio Obrero (7.1%), have flood insurance, while far more residents of the wealthiest community, University Gardens (70.0%), have flood insurance.

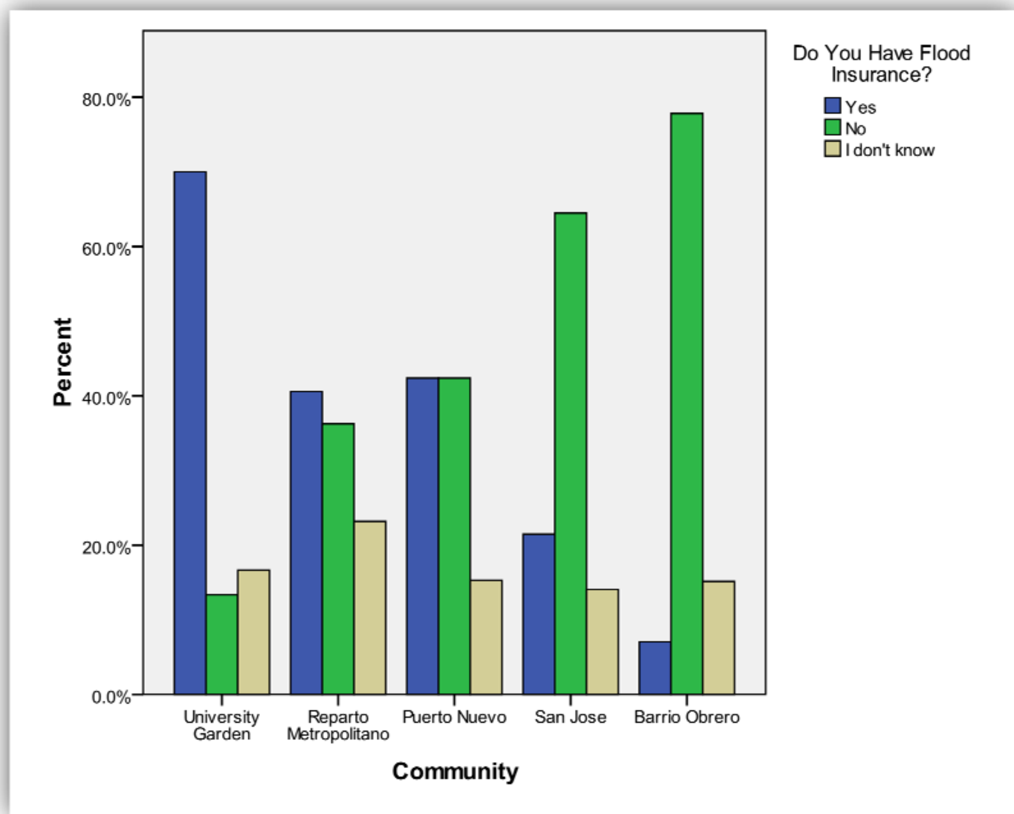

Figure 20: Flood Insurance by Community

Another question the team addressed is the connection between floods and flood damage experienced, the number of times subjects have been compensated by their insurance or by a government organization for damages, and the steps they have taken to prevent losses from future floods. Of the subjects who have not experienced flooding, only 18.6% have done anything to prevent damages from flood damages. 43.2% of subjects who have experienced at least one flood have taken measures to prevent losses. This percentage of subjects who have experienced at least one flood and have taken measures to prevent losses was also dependent on community; in wealthier communities such as University Gardens (51.7%), and Puerto Nuevo

(55.7%) the proportion is relatively high compared to the less wealthy communities, Barrio Obrero (45.1%) and San José (26.7%). Some residents of San José had been informed that their homes are going to be taken through eminent domain and they do not want to spend money to prevent flood damage to houses that they are going to lose. For those who have suffered flood damage at least once, the number of subjects who had taken measures to prevent future losses was once again higher for wealthier communities; University Gardens (72.2%), Reparto Metropolitano (69.2%), and Puerto Nuevo (66.7%) have the highest percentage of subjects suffering flood damages who had then tried to prevent future losses while the percentage in San José (58.8%) and Barrio Obrero (52.0%) was lower. Finally, the percent of residents who have taken measures to prevent future flood damages increased with the number of times they had been compensated for damages (see Figure 21).

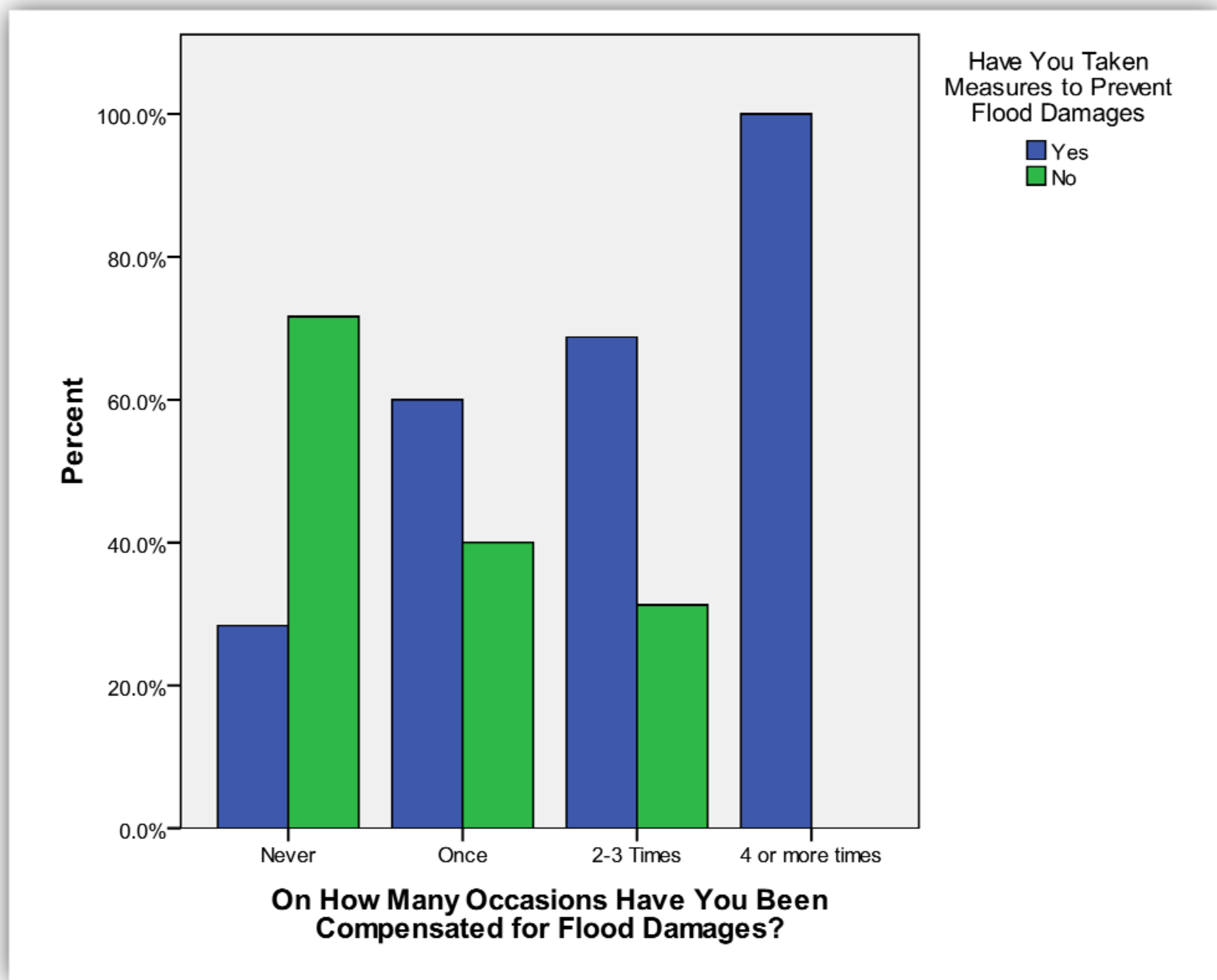

Figure 21: Compensation and Flood Damage Prevention

The most popular methods for preventing flood damage fall into three broad categories: constructing barriers, improving drainage, and raising the residence and belongings. The first category includes both permanent barriers like concrete walls to keep water out of the home and temporary measures like sand bags and panels to prevent water from entering the home through a gate or door. Residents attempt to improve the drainage near their houses to carry the floodwater away from their homes by removing garbage from nearby storm drains and drainage pipes. This is not unexpected; 44.2% of subjects identified poor drainage as a cause of flooding, and garbage was often cited as the reason drainage was inadequate. The final category of measures taken to prevent flood damage include raising the level of the floor, raising the bottom of the windows, raising the bottom of the doors, and moving electronics, furniture and other belongings onto blocks or other raised item. Many homes in the communities surveyed had been built with floors, doors, and windows level with the ground. Floodwater could easily enter homes through the doors and windows; the residents raised the doors and windows to prevent water from entering and higher floors result in lower levels of water in the home. When floodwater did enter the home, moving belongings up and away from the water kept them dry and prevented damage. Other, less common steps taken to prevent losses from floods include replacing carpet with linoleum tile on the floors, replacing furniture with pool furniture, and building pumps to remove flood water from the home. Some subjects in Reparto Metropolitano reported that although they were initially successful in keeping water from entering their homes, floodwater entered their house through the toilet.

The final section of the survey dealt with the best form for flood insurance and flood damage mitigation information, such as written information, educational talks, or visits from government officials. The subjects were encouraged to choose all forms of information they were interested in. Most subjects, 57.9%, responded that they want written information, 22.5% responded that they want educational talks for the community, and 19.1% responded that they want an official to visit their home in order to talk about flooding and flood damage prevention strategies. Although it was not presented as an option, 17.7% of subjects stated that they were not interested in information of any form.

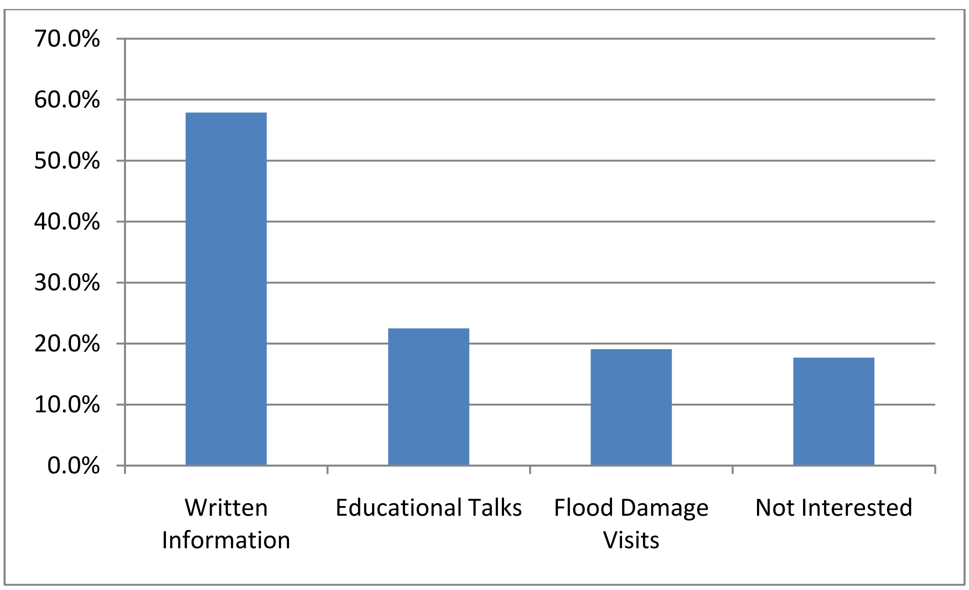

Figure 22: Preferred Form of Flood Insurance and Flood Damage Mitigation Information

4.4 Summary

This chapter presents the results created through this project; the tutorial that explains, step by step, the methodology created to estimate population in floodplains and the maps that were created using this process for the floodplains of San Juan. It also presents the results of our survey. As flooding is a large problem in Puerto Rico, the methodology will be used to determine the population of floodplains across the island and the maps created for the project and through future application of the estimation process will help La Junta de Planificación to better allocate resources during flooding events. The survey data will help La Junta de Planificación to know what information the residents of flood zones need to prevent damage to their homes and the best way to convey that information.

CHAPTER 5: CONCLUSION AND FUTURE WORK

The work done on this project will be useful in helping La Junta de Planificación to mitigate the effects of flooding on the population in Puerto Rico. The population estimate, population map, and population density map will allow better allocation of resources and the methodology used to create these products will be used in other municipalities to produce similar maps and estimates that will be used to mitigate flood damage in those areas. The survey data will be used to better understand the nature of flooding in the areas and to determine the best way to educate floodplain residents of ways they can protect themselves from floods.

Although the team achieved all of the objectives of the project, the work done on this project lends itself to further study. The methodology created for this project can be improved with a special method for adjusting the Census block populations when it is clear that one or more buildings, such as apartment buildings, have many more residents than others. The methodology can also be used to estimate the floodplain population with 2010 Census data and in other areas of Puerto Rico. Finally, the technique for compiling information used to create the maps can also be used with Hazus-MH to provide flood damage predictions

5.1 Special Estimation Procedure

The procedure used to determine the population of a Census block living in a floodplain assumes that the number of residents per building is constant within a floodplain. Based on the small size of each Census block, this is a reasonable assumption for nearly all Census blocks. In some blocks, however, there are buildings of various types with different numbers of residents and assuming that the number of residents living in each building is constant introduces error into the estimate. This error could be reduced or eliminated if during the aerial inspection process, each building in a Census block partially within a floodplain were designated as inside or outside the floodplain. Those doing the estimation would then go to these buildings and determine the number of people living in each and use those numbers in their estimation. This method of estimating the population would be very time consuming but would yield extremely accurate results.

5.2 Further Estimation

The 2010 Census was still being conducted when this project was finished. When the data from that Census becomes available, the tutorial created for this project can be used to create another, more current estimate of the population of floodplains in the municipality of San Juan. This new estimate would reflect changes in the population and density of the areas. It would also allow comparison between the two estimates, which would show changes in population and population density in these areas. Knowing how the population is changing in these flood zones is important and can be used to further allocate resources to prevent flood damage and loss of life.

The methodology for estimating floodplain population described in this report and in the tutorial can also be used to estimate the population of flood zones in other regions of Puerto Rico. Ideally, it would be carried out for each municipality and the number of people at risk of suffering flood damage could be determined for the entire island. This methodology is not specific to Puerto Rico; it could be applied to floodplains around the world.

5.3 Hazus-MH

While the team researched Hazus-MH, several obstacles kept the team from being able to use it during the course of the project. It took several weeks to obtain a copy of the program and the copy was incompatible with all computers available to the team. Furthermore, to use Hazus-MH, ArcGIS 9.3 with a corresponding Spatial Analysis extension is required, which was also unavailable. The team believes, however, that Hazus-MH would be useful to provide more detail about the possible damages associated with a serious flooding event, especially in terms of economic damage sustained. The team also believes that the information created using the population estimation tutorial would serve as a foundation for the information needed to run very specific simulations of flooding events in the affected areas. Because of its potential benefits, applying Hazus-MH to the floodplains of San Juan would be a good opportunity for future teams from WPI. Other information required would include hydrology and economic data; the hydrology data is already available from the same sources as the other information used in this project. Economic data would have to come from another source, such as surveys or from an economic expert familiar with the area.

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APPENDIX A: ENGLISH SURVEY

FLOOD INSURANCE IN SAN JUAN

The information you provide will be used to draw general conclusions about flood insurance, flood awareness and demographics in your neighborhood. All answers will be kept confidential and will not be used to identify you. You may stop taking this survey at any time if you feel uncomfortable or are unwilling to continue.

DEMOGRAPHIC INFORMATION

1. What is your age?
- ☐ 0-15
- ☐ 16-25
- ☐ 26-35
- ☐ 36 or more

2. What is your gender?
- ☐ Male
- ☐ Female

3. How many people live in this residence?

_____

HOUSING INFORMATION

4. How many years have you lived at this residence?
- ☐ 1-4
- ☐ 5-10
- ☐ 11-15
- ☐ 16 or more

5. Where does the owner of this residence live?
- ☐ I own this residence
- ☐ In this building
- ☐ Nearby
- ☐ In another neighborhood
- ☐ I am unsure

6. What is the foundation made of?
- ☐ Wood
- ☐ Concrete

7. What is the siding made of?
- ☐ Wood
- ☐ Metal
- ☐ Concrete
- ☐ Other

FLOODING INFORMATION

8. Are you aware your house is in an area designated by FEMA as a floodplain?
- ☐ Yes
- ☐ No

9. What flooding problems affect your neighborhood?
- ☐ Drainage problems during low-intensity rain
- ☐ Drainage problems during high-intensity rain

FLOOD INSURANCE INFORMATION

10. Do you have any flood insurance?
- ☐ Yes
- ☐ No
- ☐ Unsure

11. How many floods have you experienced while living in this residence?
- ☐ 0
- ☐ 1-2
- ☐ 3-4
- ☐ 5+

11a. If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?
- ☐ 0-2
- ☐ 3-5
- ☐ 6 or more

11b. How many times have you experienced flood damage to this residence?
- ☐ 0
- ☐ 1-2
- ☐ 3-5
- ☐ 6+

12. Have you ever been compensated for damage at this residence? If so, on how many occasions?

FECHA________________________

- [ ] I have never been compensated
- [ ] 1
- [ ] 2-3
- [ ] 4+

COMMUNIDAD:________________

12a. If you have been compensated, what kind of aid did you receive?

- [ ] Flood insurance payment
- [ ] Federal assistance
- [ ] Municipal assistance
- [ ] Central Government assistance
- [ ] I do not know

13. Have you taken measures to prevent flood damage?

- [ ] Yes
- [ ] No

13a. If so, what have you done?

____

____

____

13b. Which of these have been the most effective?

____

____

____

14. What kind of information would you like to receive about flood damage prevention?

- [ ] Written materials
- [ ] Educational talks
- [ ] A visit to go over flood damage prevention strategies

APPENDIX B: SPANISH SURVEY

Seguro de inundación
en San Juan

La información que provea en este cuestionario se usará para llegar a conclusiones generales sobre los seguros de inundación, concientización sobre inundaciones y las características demográficas de su vecindario. Todas las contestaciones serán confidenciales y no se utilizarán para identificarle. Puede dejar de contestar el cuestionario en cualquier momento que se sienta incómodo o no desee seguir contestándolo.

Información demográfica

1. ¿A qué grupo de edad pertenece?
- ☐ 0-15
- ☐ 16-25
- ☐ 26-35
- ☐ 36 o más

2. ¿Cuál es su género?
- ☐ Femenino
- ☐ Masculino

3. ¿Cuántas personas viven en esta residencia?

_____

Información sobre la residencia

4. ¿Cuánto tiempo hace que vive en esta residencia?
- ☐ 1 a 4 años
- ☐ 5 a 10 años
- ☐ 11 a 15 años
- ☐ 16 años o más

5. ¿Dónde vive el dueño de la residencia?
- ☐ Soy el dueño
- ☐ En este edificio
- ☐ Cerca
- ☐ En otro vecindario
- ☐ No sé

6. ¿La fundación de esta residencia es de?
- ☐ De cemento
- ☐ De madera

7. ¿Las paredes son de?
- ☐ Madera
- ☐ Metal
- ☐ Cemento
- ☐ Otro__________________

Información sobre inundaciones

8. ¿Está consciente que su hogar está en un área inundable según designado por FEMA?
- ☐ Sí
- ☐ No

9. ¿Qué problemas de inundación afectan a su vecindario?
- ☐ Problemas de drenaje con lluvias de poca intensidad
- ☐ Problemas con lluvias intensivas

Información sobre seguro de inundación

10. ¿Tiene seguro por inundación?
- ☐ Sí
- ☐ No
- ☐ No sé

11. ¿Cuántas inundaciones ha experiementado desde que vive en esta residencia?
- ☐ 0
- ☐ 1-2
- ☐ 3-4
- ☐ 5 o más

11a. ¿Si ha experimentado inundaciones en esta residencia, cuán alta ha sido, en pies?
- ☐ 0-2
- ☐ 3-5
- ☐ 6 or más

11b. ¿Cuántos veces de éstas ha sufrido daños por la inundación?
- ☐ 0
- ☐ 1-2
- ☐ 3-5
- ☐ 6 o más

12. ¿Ha sido compensado alguna vez por el daño a esta residencia? Si acaso,

- ☐ Nunca he sido compensado
- ☐ Una vez
- ☐ 2-3 veces
- ☐ Cuatro o más

FECHA________________________

COMMUNIDAD:_________________

12a. Si ha sido compensado, ¿qué ayuda recibío?

- ☐ Pago por el seguro
- ☐ Ayuda federal
- ☐ Ayuda del gobierno municipal
- ☐ Ayuda por el gobierno central
- ☐ No sé

13. ¿Ha tomado medidas para prevenir la pérdida por inundación?

- ☐ Sí
- ☐ No

13a. Si acaso, ¿qué ha hecho?

____

____

____

13b. ¿Cuáles de estas medidas han sido más efectivas?

____

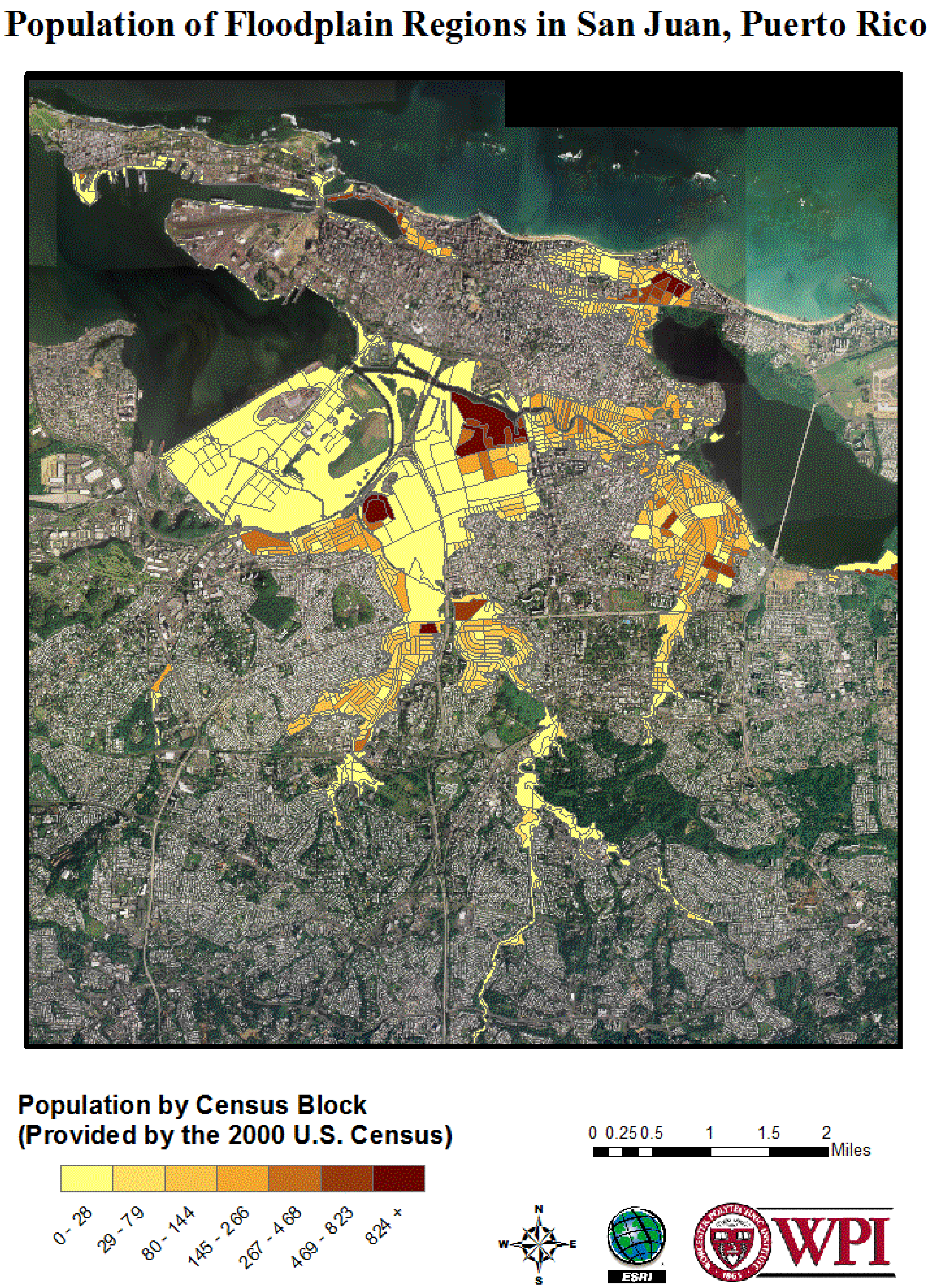
____

____

14. ¿Qué tipo de información le gustaría recibir sobre prevención de daños por inundación?

- ☐ Información escrita
- ☐ Charlas educativas
- ☐ Una visita para habira sobre estrategias para prevenir daños

APPENDIX C: POPULATION MAP



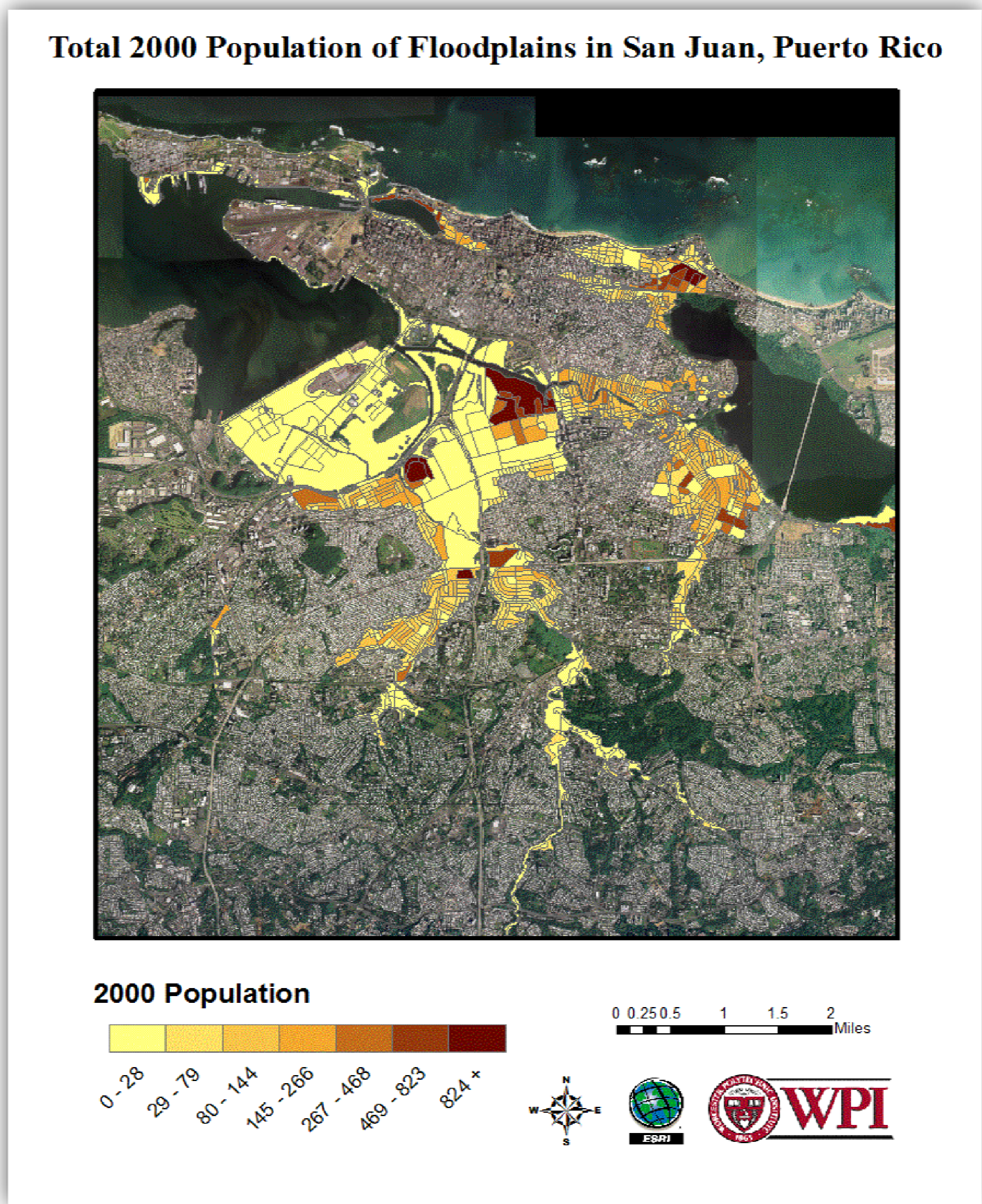
APPENDIX D: POPULATION DENSITY MAP

Population Density of Floodplain Regions in San Juan, Puerto Rico

APPENDIX E: POPULATION ESTIMATION TUTORIAL

Population Estimation Tutorial

Prepared by Thomas Cucinotta, Jay Devenger, Lane Thornton, and David Vecchiarelli



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Introduction

The purpose of this document is to demonstrate a methodology for estimating the population living in a floodplain. This tutorial provides instruction for the process of collecting the necessary data, adjusting the Census blocks that are not completely contained within a floodplain, creating a population map, and the steps to produce the finished map. Following the steps in this document, the user will learn to:

- Upload files to ArcGIS.
- Use the Clip tool to edit layers.
- Change the properties of layers.
- Set up ArcGIS in a way that allows the user to effectively count houses within Census blocks.
- Create population maps using the symbology menu of ArcGIS.
- Export data from ArcGIS layers.
- Use the Select Features and Statistics tools to find populations of areas.
- Use Layout View to add a title, legend, scale bar, and north arrow to a map.
- Export a map.

Upon completion of this tutorial the user should have acquired an understanding of ArcGIS and Census data. The products that will result from this tutorial are a population map, and an estimate of the population within the floodplain(s).

Getting Started

Before you get started, you will need a computer equipped with the proper software and data files.

Necessary Software:

- ArcGIS 9.2 or higher
- Open Office 3.2 or higher
- Microsoft Excel 2007 or higher

Necessary Files:

- Aerial photographs of the floodplain and surrounding area. These aerial photographs are obtained from a map database maintained by the Jacksonville District of the USACE.
- FIRM Map files of the floodplains under study. These are obtained from the Federal Emergency Management Agency (FEMA).
- Census Blocks containing U.S. Census population data. This data is obtained from a map database maintained by La Junta de Planificación. It can also be found in the U.S. Census Tiger Files Database at http://www.census.gov/geo/www/tiger/.

Step 1: Uploading Files into ArcGIS 9.2

The first step towards a population estimate is uploading the correct files into ArcGIS 9.2. First, **open** *ArcGIS* and **select** the *A new empty map* option and **click** *OK*.

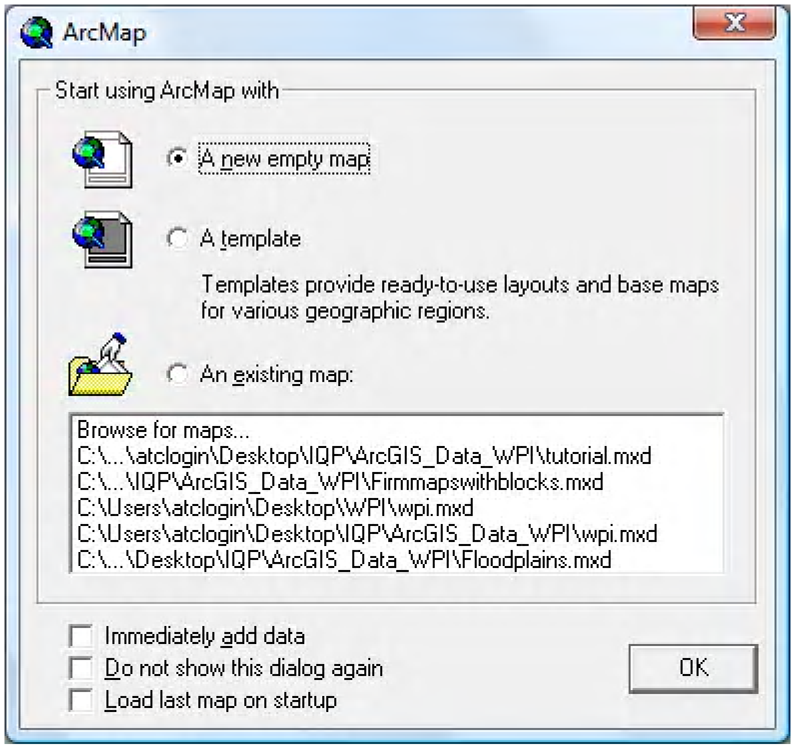


Figure 1: Opening Screen

Adding FIRM Maps

Click the *Add Data* button on the toolbar. Find the folder where the FIRM map data is saved. These files will be called *firmmaps_areas.* **Select** these files and **click** *Add*.

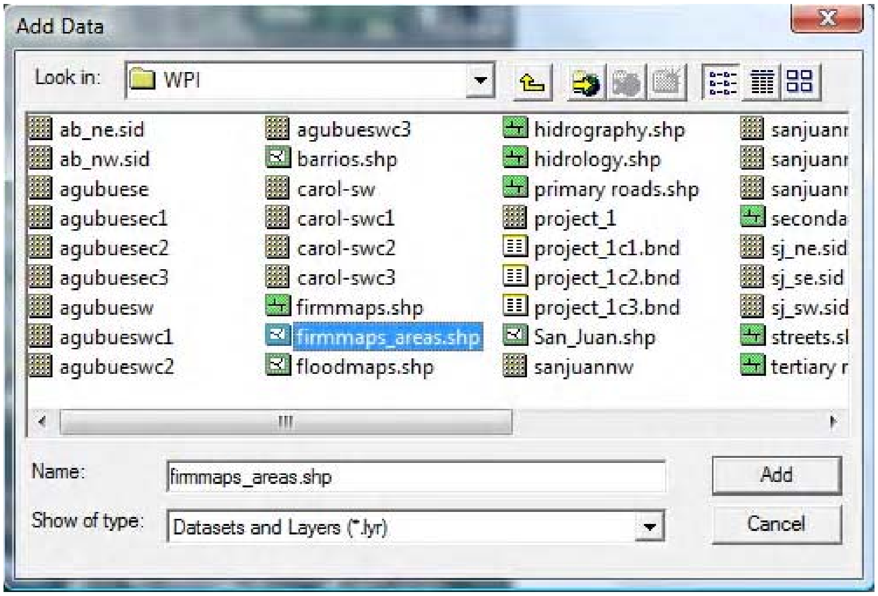


Figure 2: Adding FIRM Map Data

Right-click on *firmmaps_areas* . **Click** on *Properties,* then **click** on the *Symbology* tab. **Click** *Categories*. Under *Value Field*, **click** *Flood_Zone*, then *Add All Values*. **Click** *Apply*, then *OK*. In this example, FIRM map data has been uploaded for the entire municipality of San Juan. The resulting screen should look like Figure 3.

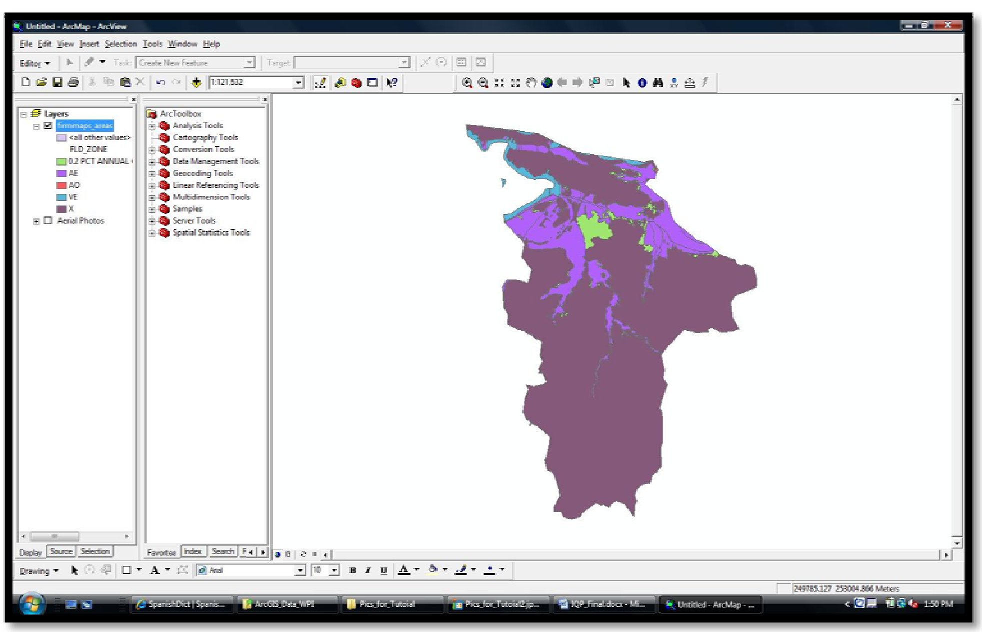


Figure 3: Uploaded FIRM Map Data

Adding Aerial Photos:

Click the *Add Data* button on the toolbar. **Find** the folder where the aerial photograph files are saved, **select** them, and **click** *Add*.

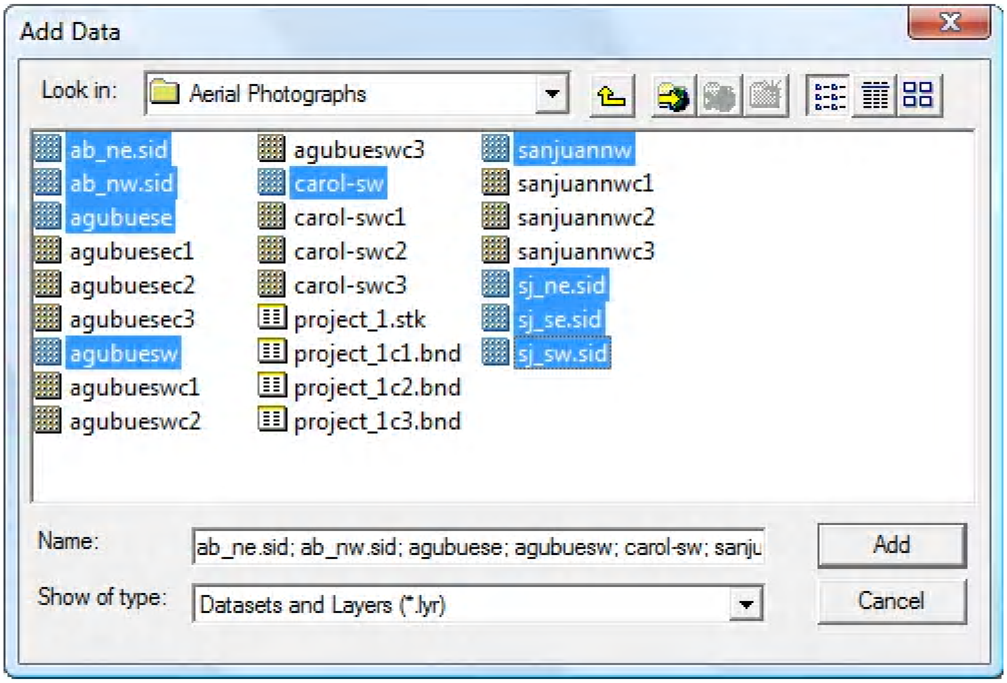


Figure 4: Adding Aerial Photos

The resulting screen should look like Figure 5. In this example, twenty-one files were uploaded to cover the entire Municipality of San Juan.

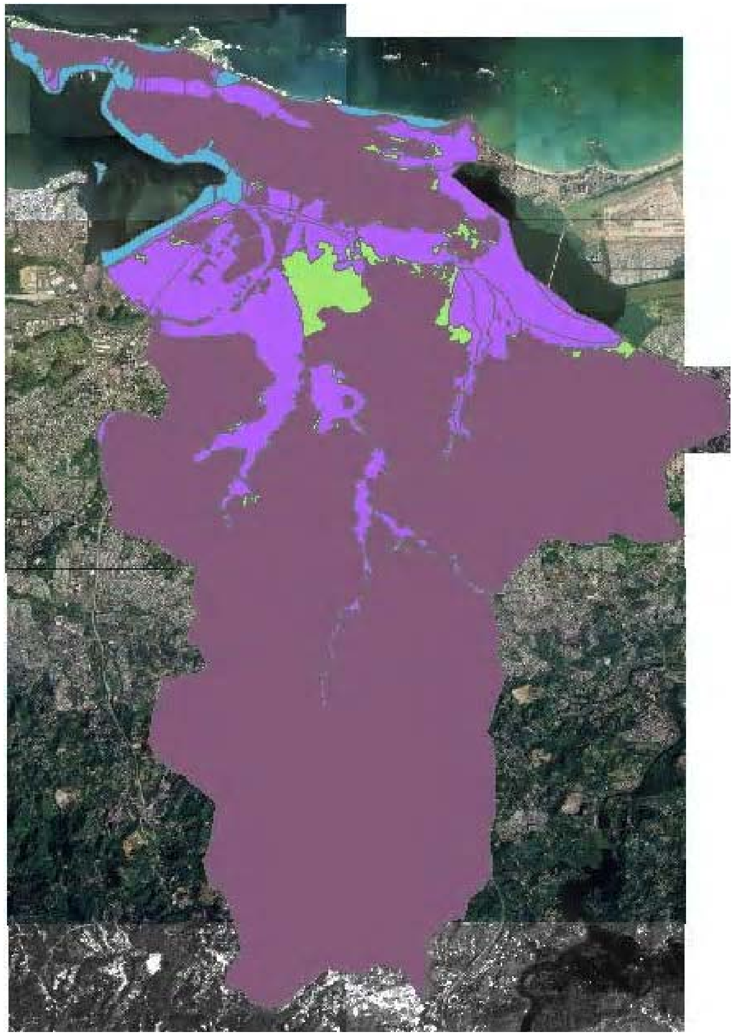


Figure 5: Uploaded Aerial Photos

The next step is to consolidate all aerial photos into one layer. **Right-click** on *Layers* and **select** *New Group Layer*. **Rename** this layer *Aerial Photos*. **Drag** and **drop** each aerial photo layer into *Aerial Photos*. Then **drag** and **drop** the *Aerial Photos* layer under the FIRM maps, so that the FIRM maps appear on top of the aerial photos.

Adding Census Blocks

Click the *Add Data* button on the toolbar. **Find** the folder where the Census Block files are saved, **select** them, and **click** *Add*.

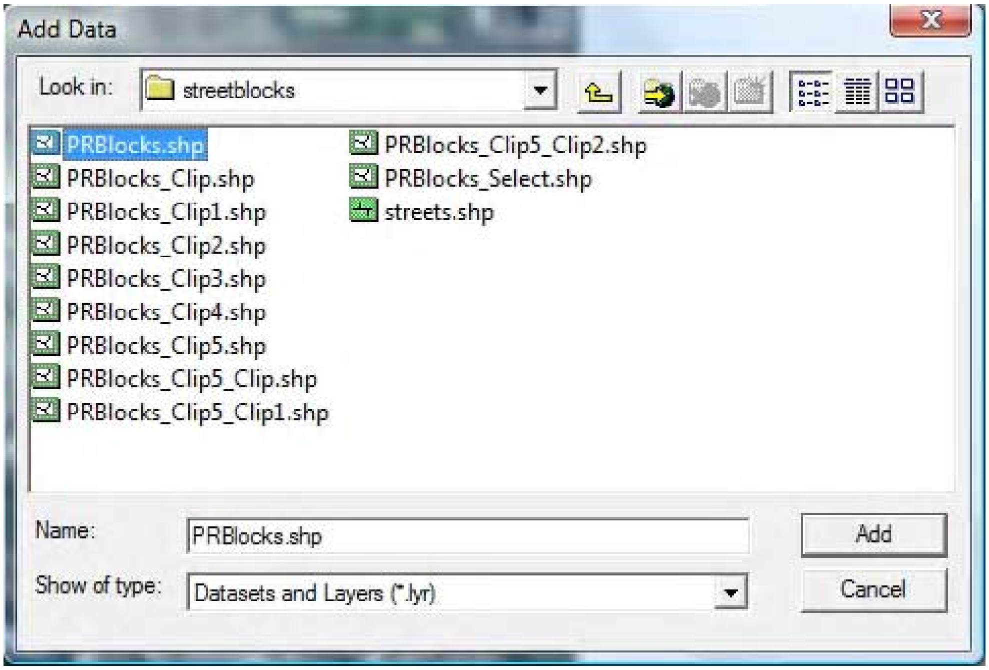


Figure 6: Adding Census Blocks

The resulting screen should look like Figure 7.

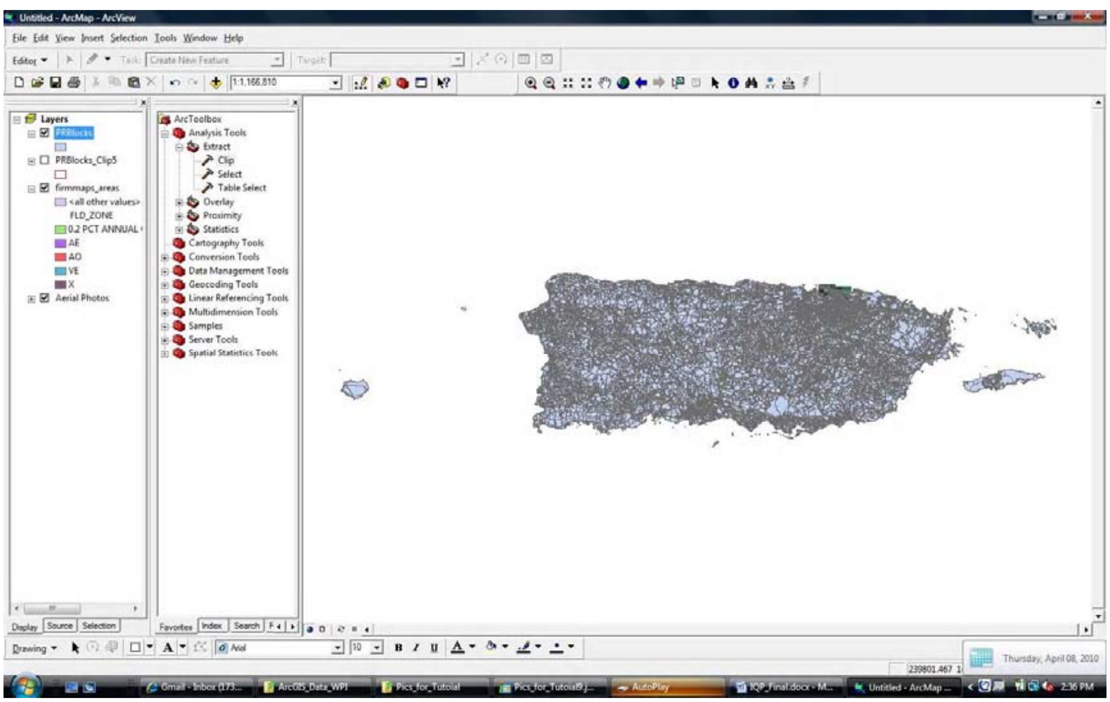


Figure 7: Uploaded Census Blocks

In this example, all of the Census blocks for Puerto Rico were added. It is not necessary to have any Census blocks outside of the areas of interest, so the next step is to **clip** the Census block layer within the area covered by the aerial photo. In the Arc Toolbox, **expand** *Analysis Tools*, **expand** *Extract*, and **double-click** *Clip*. The Clip Tool will open. For the *Input Features*, **select** the Census Blocks layer, called PRBlocks in this tutorial, from the drop-down menu. **Select** the FIRM map layer from the drop-down menu and **click** *OK*.

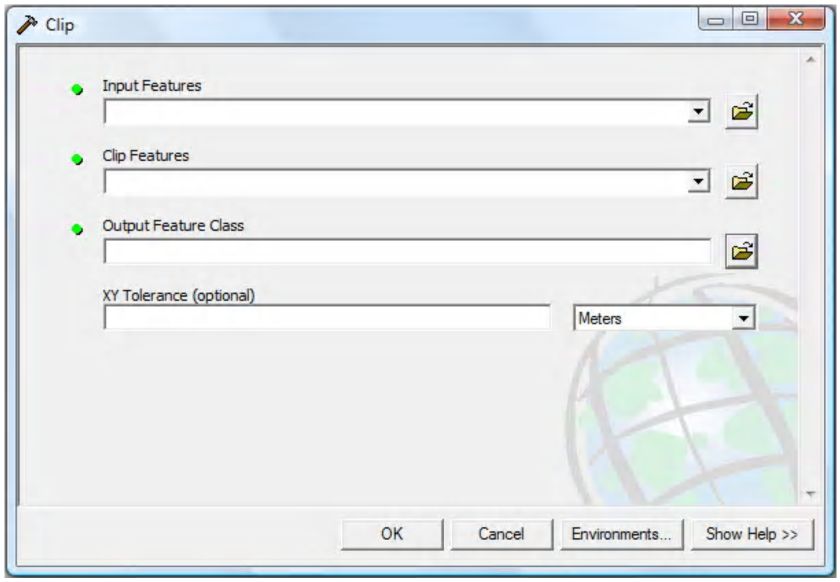


Figure 8: Clipping the Census Blocks

When the clip tool has finished, **click** *Close* on the clip window. This will create a new layer that will include all Census blocks within the desired area. In this example, the clipped layer includes all Census blocks within the Municipality of San Juan. To remove the original Census block layer, **right-click** on it and **click** on *Remove*. This should result in a screen like Figure 9.

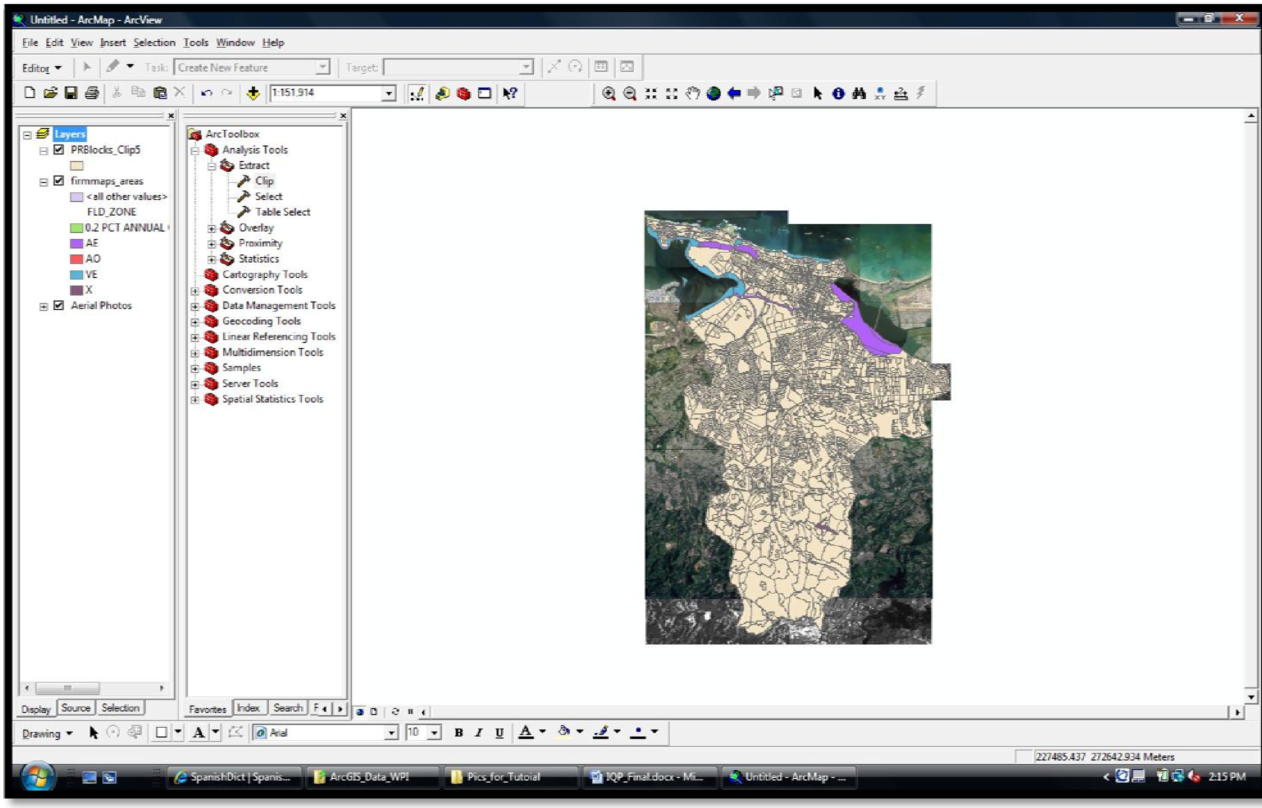


Figure 9: Clipped Census Blocks

All of the necessary files are now uploaded. Each layer can be turned off and on individually by **checking** and **un-checking** the boxes next to each layer. Next, **double-click** on the colored box under the name of the Census block layer. **Select** *Hollow* and **select** *2.00* for the *Outline Width*. **Choose** a distinct color for *Outline Color* and **click** *OK*. In this example, red is used as the *Outline Color*.

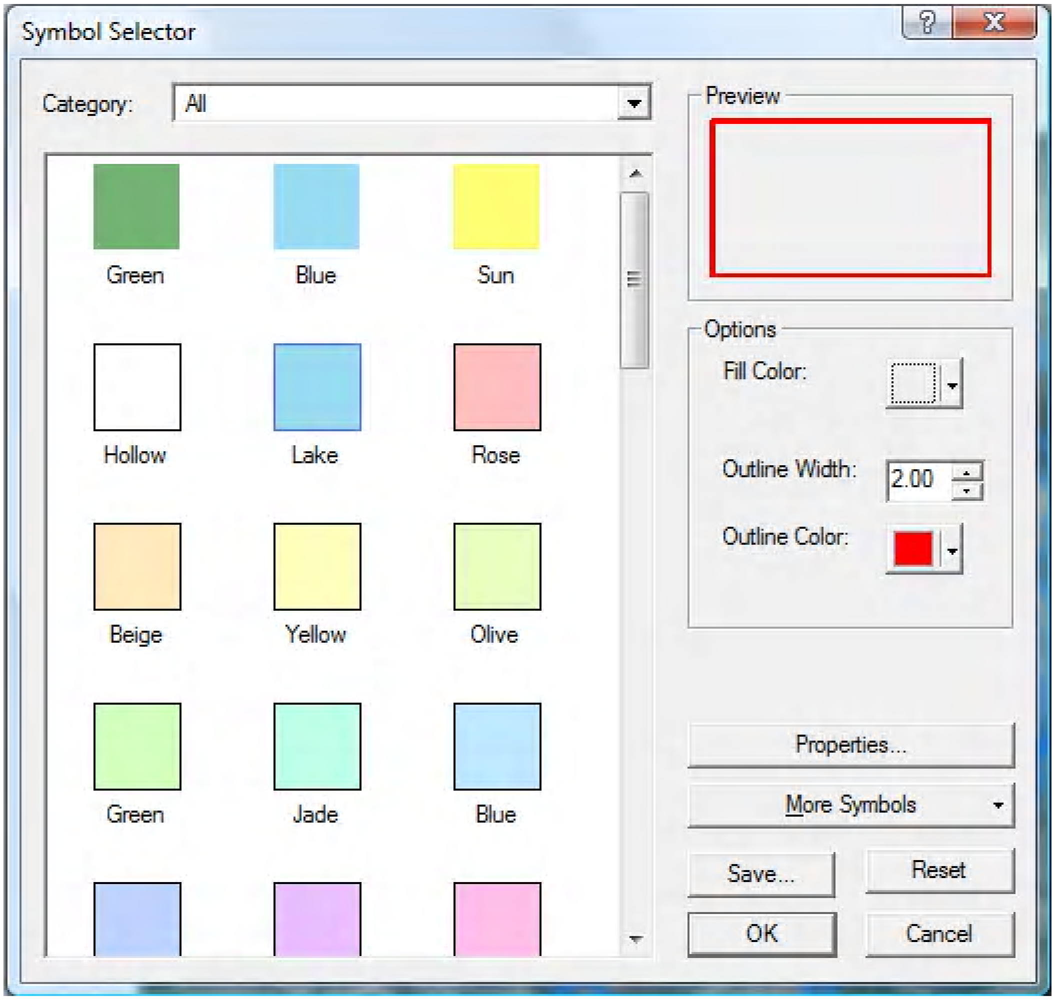


Figure 10: Changing Census Block Color

The resulting screen should look like Figure 11. This is the end of Step 1: Uploading Files into ArcGIS 9.2. All of the necessary files are uploaded and prepared for Step 2: Selecting a Floodplain.

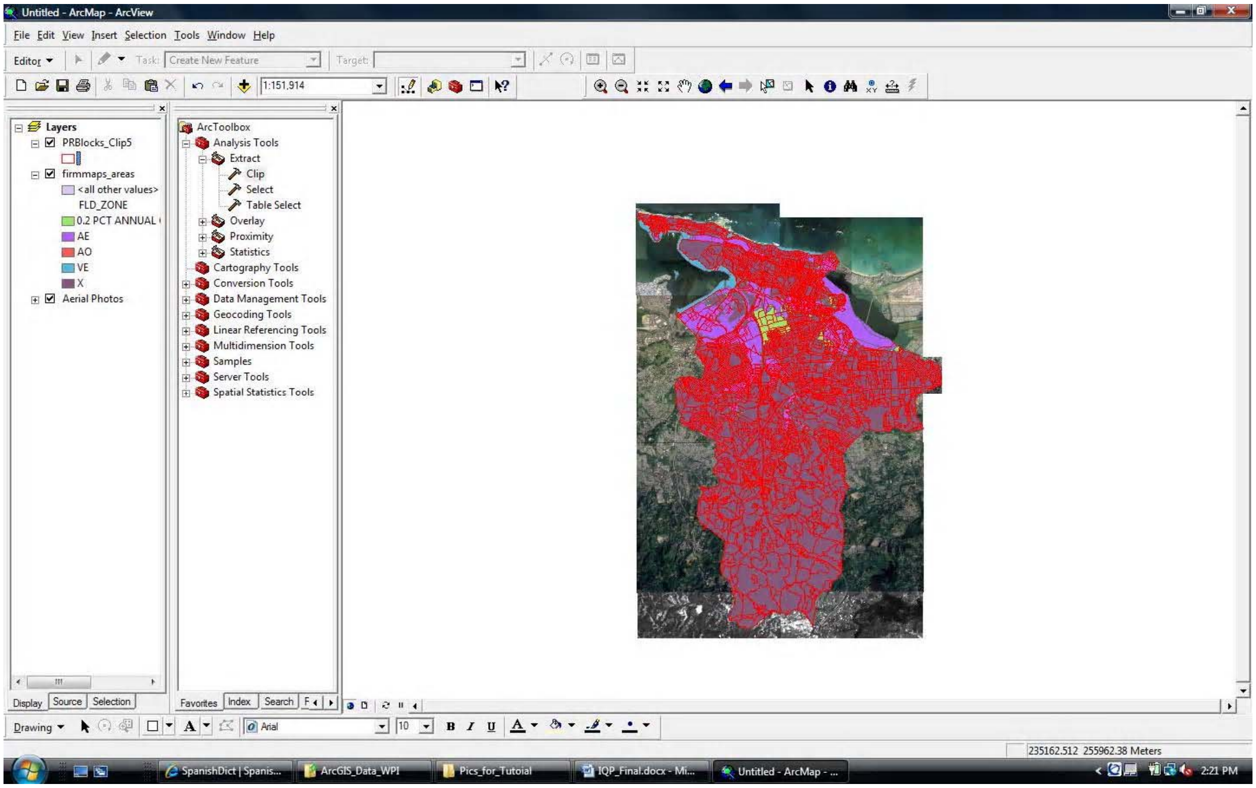


Figure 11: FIRM Map with Census Block Outline

Step 2: Selecting a Floodplain

The FIRM map layer is broken up into 5 distinct floodplain designations. They are *0.2 Percent Annual Chance*, *AE*, *AO*, *VE,* and *X*. Each designation represents areas with different flood insurance rates. The *X* designation represents areas that where flood insurance is not required. The steps for calculating the population of each other designation are identical, so only one such procedure is detailed in this document. This example uses the *AE* designation.

In order to highlight the floodplain designation under immediate study, **right-click** on the FIRM Map layer, and **select** *Properties.* In the *Layer Properties* menu, **select** each floodplain designation not under study and **click** *Remove*. Figure 12 shows the *Layer Properties* menu after the removal of all but *AE* floodplains.

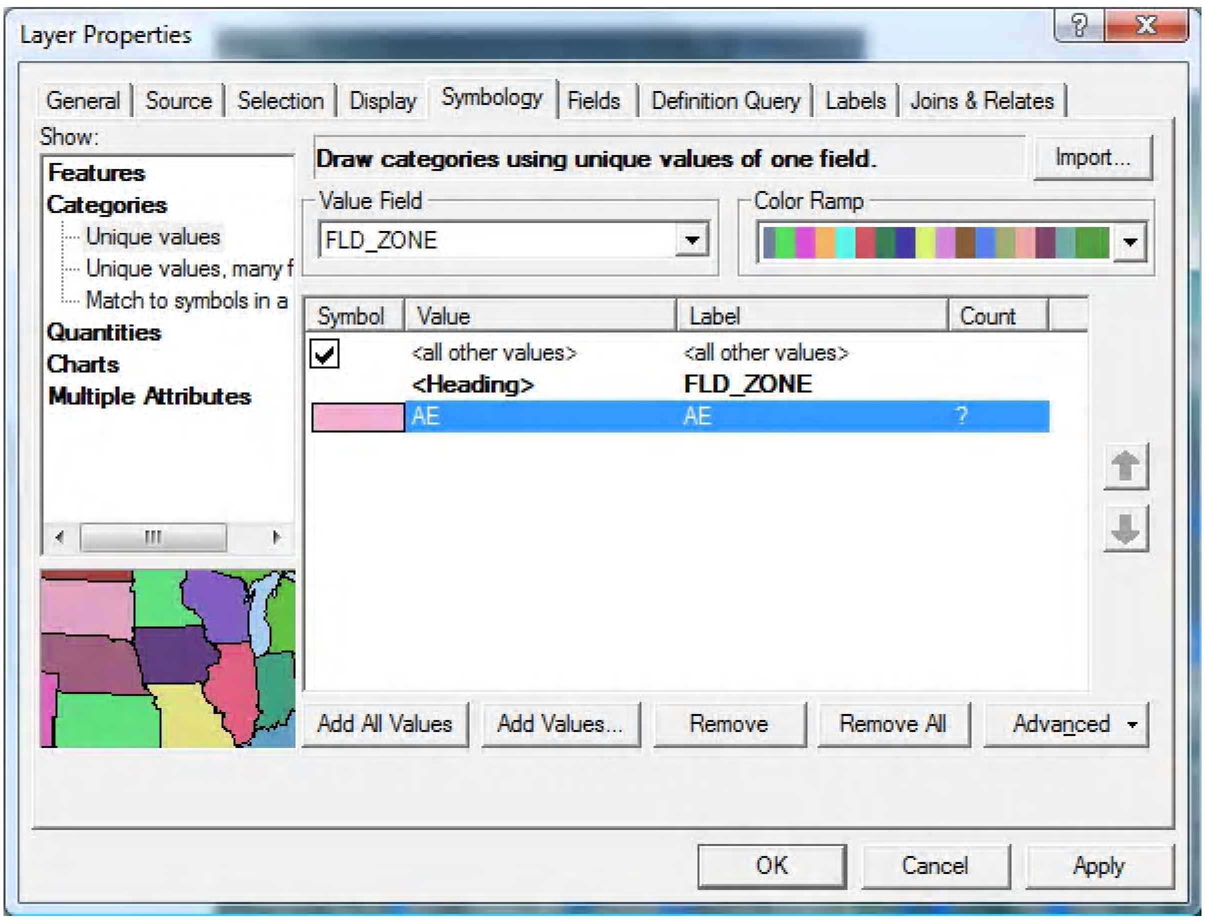


Figure 12: Final Layers Property Menu

Click *Apply* and then *OK*. **Double-click** the colored square next to *All Other Values* under the FIRM map layer. **Select** *Hollow* and **click** *OK*. **Double-click** the colored square next to the flood zone designation under the FIRM map layer. **Select** a color for the flood region. In this example, *10% Simple Hatch* is used in order to allow the aerial photo to be seen beneath the hatch marks. **Select** 2 for the *Outline Width* and distinct color for both *Fill Color* and *Outline Color* and **click** *OK.*

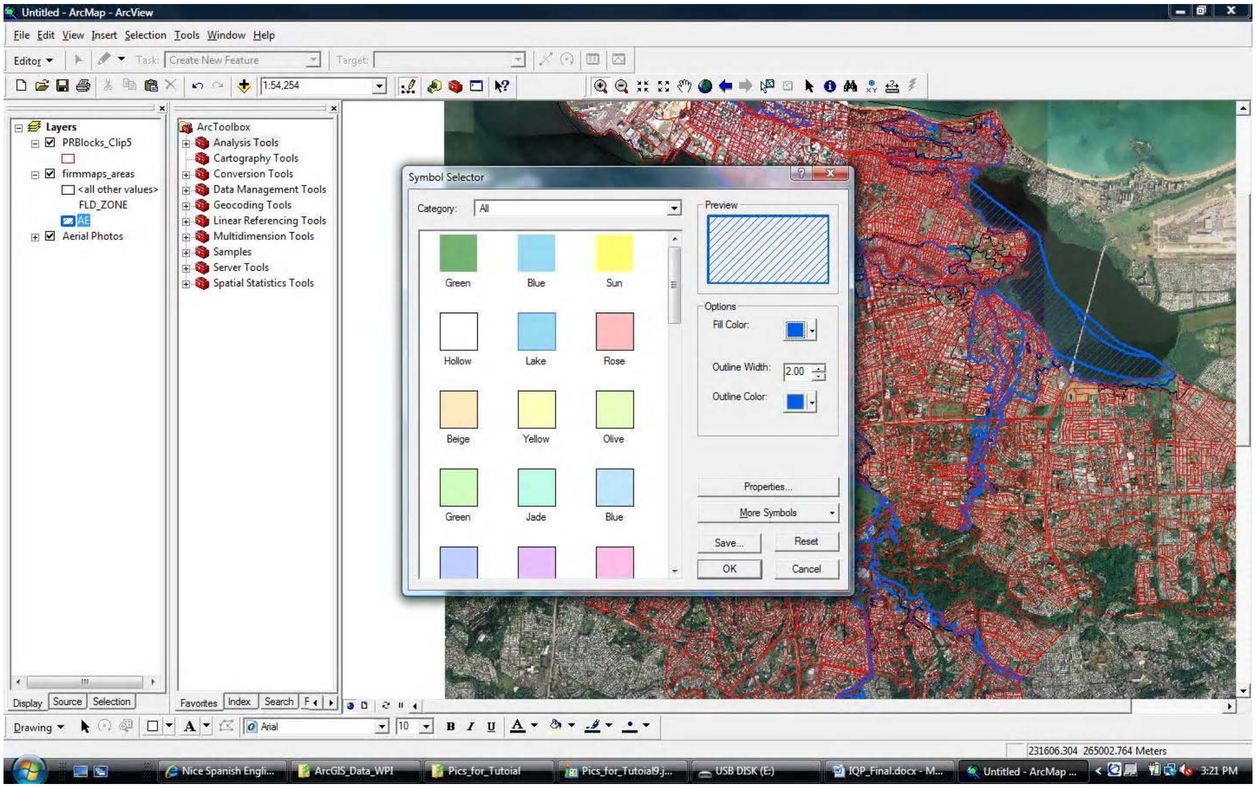


Figure 13: Selecting Floodplain Color

Figure 14 shows a magnified view of a community in San Juan within an AE floodplain. The blue hatch represents the area within the floodplain and the red lines represent the Census block boundaries. The buildings in the aerial photograph can be easily seen through the hatch. The map is now ready for Step 3: Counting and Population .

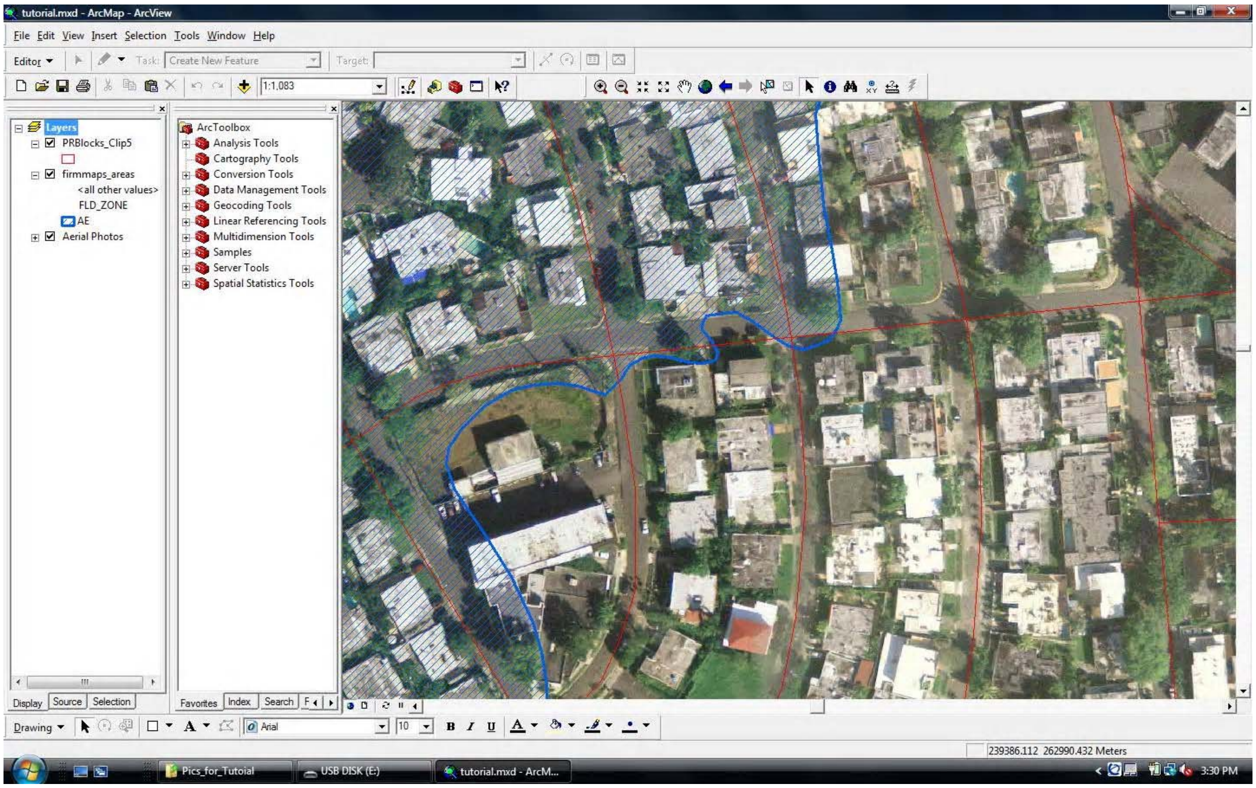


Figure 14: A Community in an AE Flood Region with Census Block Boundaries

Step 3: Counting and Population Estimation

To determine how many people reside in the floodplain, it is necessary to estimate the population in each of the Census blocks that are also in the floodplain. By following the instructions in this section, a list of all of the Census blocks with the necessary information about each of these blocks needed to estimate the population will be created. Each step below explains how to obtain the following information: the ID number for each of the blocks, the population within each of the blocks, the number of households within each of the blocks, the number of buildings in that block which are in the floodplain, and the number of buildings in the block that are not in the floodplain.

Setting up the Spreadsheet

To create a layer of Census blocks within a specific floodplain, decide the specific zone to set as the outline of the floodplain. **Click** the *Selection* tab, and then **select** *Select by Attributes...* which then displays the window shown in Figure 15.

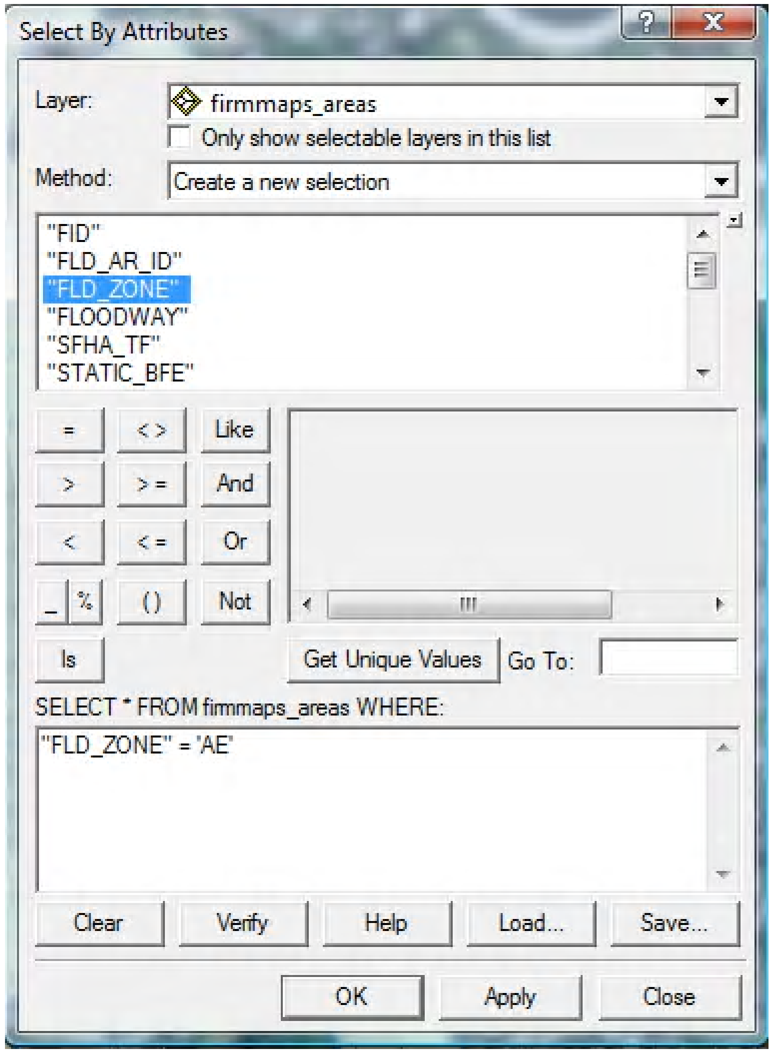


Figure 15: Select Attributes Window

Select firmmaps_areas as the *Layer*. In the field under Methods, **double Click** on “FLD_ZONE”, then **click** = and then *Get Unique Values*. **Choose** the desired zone (in this example it is the AE Zone). The equation in the window should read *“FLD_ZONE”=’AE’*. **Click** *OK*. This selects the chosen floodplain region. Next **right click** on *firmmaps_areas*, **click** *Selection* and **Click** *Create Layer From Selected Features*, as shown in Figure 16.

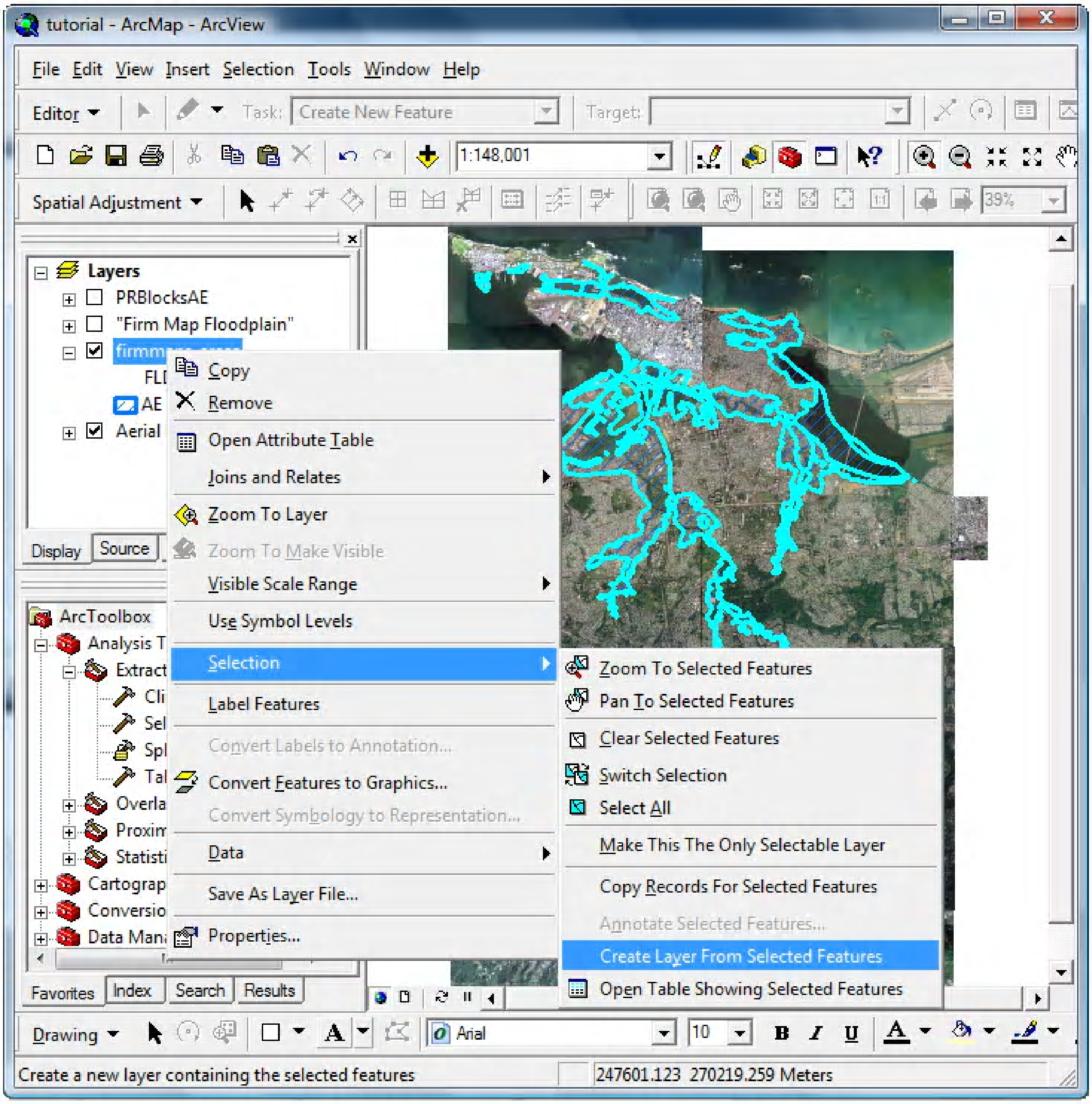


Figure 16: Creating a layer of a specific FIRM map floodplain region

This creates a new layer of a specific FIRM Map Floodplain. Next, it is necessary to create a layer of the Census blocks outlined by each of the floodplains using the *Clip* tool described in Step 1:

Uploading Files into ArcGIS 9.2. **Select** *Analysis Tools*, then *Extract*, then *Clip*, and the *Clip* tool is shown in Figure 8.

Choose *Census Blocks* as the input feature, and the *firmmaps_areas selection* as the clip feature. **Type** *PRBlocksAE* in the highlighted part of *Output Feature Class* field displayed in Figure 17. This determines the name that the new layer will be saved as. **Click** *OK* to create a layer that allows visual inspection of the floodplains and the population inside of them.

Figure 17: Changing the Output Feature file name

ArcGIS also automatically generates an attribute table associated with the layer which provides the Census blocks within the flood region, and Census data about each block. To open this attribute table, **right-click** on the *PRBlocksAE* layer and **select** *Open Attribute Table,* as displayed in Figure 18.

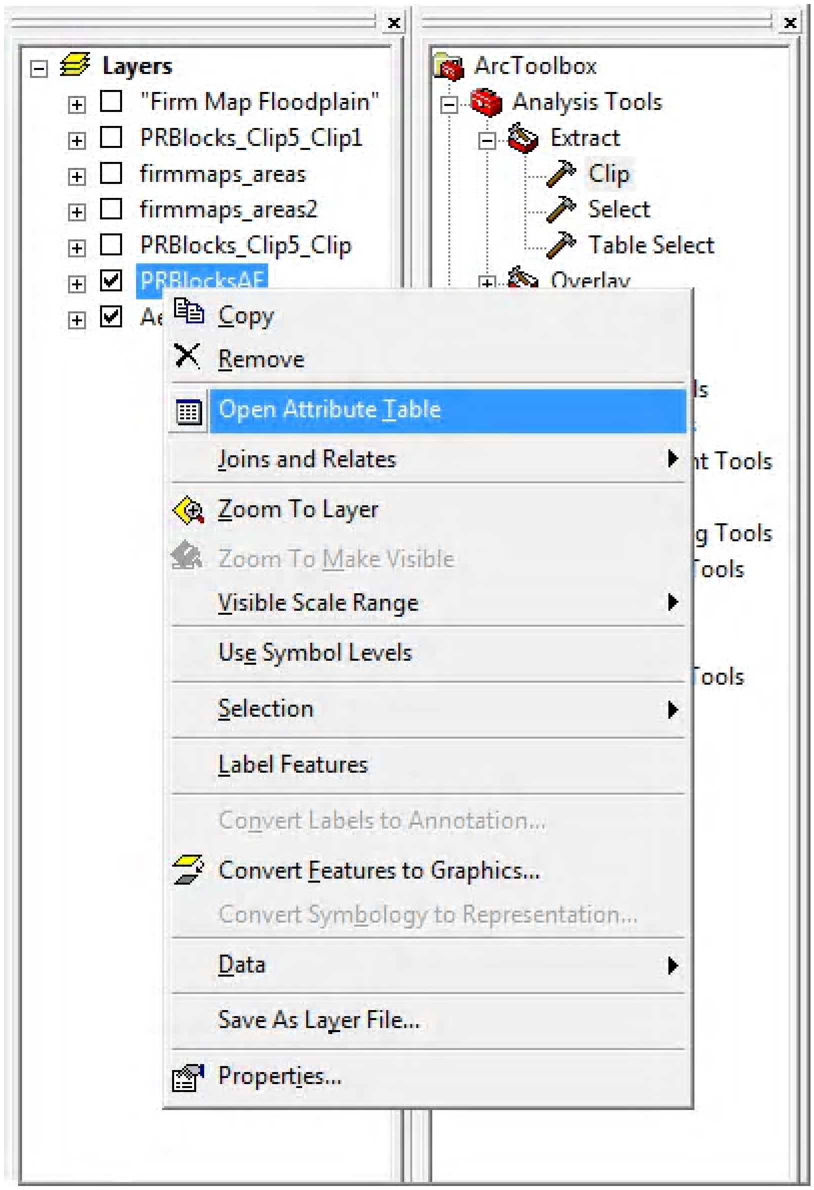
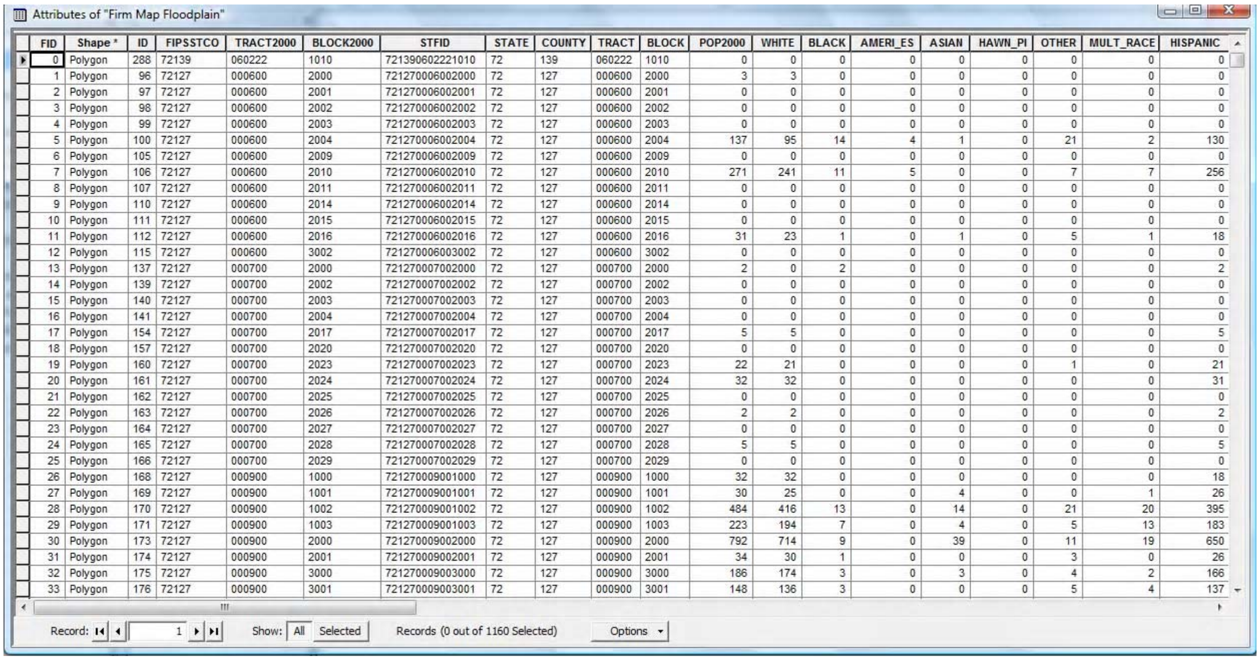


Figure 18: How to Open the Attribute Table

A table like the one in Figure 19 will appear.


Attributes of "Firm Map Floodplain"

FID	Shape *	ID	FIPSSTCO	TRACT2000	BLOCK2000	STFID	STATE	COUNTY	TRACT	BLOCK	POP2000	WHITE	BLACK	AMERI_ES	ASIAN	HAWN_PI	OTHER	MULT_RACE	HISPANIC
0	Polygon	288	72139	060222	1010	721390602221010	72	139	060222	1010	0	0	0	0	0	0	0	0	0
1	Polygon	96	72127	000600	2000	721270006002000	72	127	000600	2000	3	3	0	0	0	0	0	0	0
2	Polygon	97	72127	000600	2001	721270006002001	72	127	000600	2001	0	0	0	0	0	0	0	0	0
3	Polygon	98	72127	000600	2002	721270006002002	72	127	000600	2002	0	0	0	0	0	0	0	0	0
4	Polygon	99	72127	000600	2003	721270006002003	72	127	000600	2003	0	0	0	0	0	0	0	0	0
5	Polygon	100	72127	000600	2004	721270006002004	72	127	000600	2004	137	95	14	4	1	0	21	2	130
6	Polygon	105	72127	000600	2009	721270006002009	72	127	000600	2009	0	0	0	0	0	0	0	0	0
7	Polygon	106	72127	000600	2010	721270006002010	72	127	000600	2010	271	241	11	5	0	0	7	7	256
8	Polygon	107	72127	000600	2011	721270006002011	72	127	000600	2011	0	0	0	0	0	0	0	0	0
9	Polygon	110	72127	000600	2014	721270006002014	72	127	000600	2014	0	0	0	0	0	0	0	0	0
10	Polygon	111	72127	000600	2015	721270006002015	72	127	000600	2015	0	0	0	0	0	0	0	0	0
11	Polygon	112	72127	000600	2016	721270006002016	72	127	000600	2016	31	23	1	0	1	0	5	1	18
12	Polygon	115	72127	000600	3002	721270006003002	72	127	000600	3002	0	0	0	0	0	0	0	0	0
13	Polygon	137	72127	000700	2000	721270007002000	72	127	000700	2000	2	0	2	0	0	0	0	0	2
14	Polygon	139	72127	000700	2002	721270007002002	72	127	000700	2002	0	0	0	0	0	0	0	0	0
15	Polygon	140	72127	000700	2003	721270007002003	72	127	000700	2003	0	0	0	0	0	0	0	0	0
16	Polygon	141	72127	000700	2004	721270007002004	72	127	000700	2004	0	0	0	0	0	0	0	0	0
17	Polygon	154	72127	000700	2017	721270007002017	72	127	000700	2017	5	5	0	0	0	0	0	0	5
18	Polygon	157	72127	000700	2020	721270007002020	72	127	000700	2020	0	0	0	0	0	0	0	0	0
19	Polygon	160	72127	000700	2023	721270007002023	72	127	000700	2023	22	21	0	0	0	0	1	0	21
20	Polygon	161	72127	000700	2024	721270007002024	72	127	000700	2024	32	32	0	0	0	0	0	0	31
21	Polygon	162	72127	000700	2025	721270007002025	72	127	000700	2025	0	0	0	0	0	0	0	0	0
22	Polygon	163	72127	000700	2026	721270007002026	72	127	000700	2026	2	2	0	0	0	0	0	0	2
23	Polygon	164	72127	000700	2027	721270007002027	72	127	000700	2027	0	0	0	0	0	0	0	0	0
24	Polygon	165	72127	000700	2028	721270007002028	72	127	000700	2028	5	5	0	0	0	0	0	0	5
25	Polygon	166	72127	000700	2029	721270007002029	72	127	000700	2029	0	0	0	0	0	0	0	0	0
26	Polygon	168	72127	000900	1000	721270009001000	72	127	000900	1000	32	32	0	0	0	0	0	0	18
27	Polygon	169	72127	000900	1001	721270009001001	72	127	000900	1001	30	25	0	0	4	0	0	1	26
28	Polygon	170	72127	000900	1002	721270009001002	72	127	000900	1002	484	416	13	0	14	0	21	20	395
29	Polygon	171	72127	000900	1003	721270009001003	72	127	000900	1003	223	194	7	0	4	0	5	13	183
30	Polygon	173	72127	000900	2000	721270009002000	72	127	000900	2000	792	714	9	0	39	0	11	19	650
31	Polygon	174	72127	000900	2001	721270009002001	72	127	000900	2001	34	30	1	0	0	0	3	0	26
32	Polygon	175	72127	000900	3000	721270009003000	72	127	000900	3000	186	174	3	0	3	0	4	2	166
33	Polygon	176	72127	000900	3001	721270009003001	72	127	000900	3001	148	136	3	0	0	0	5	4	137

Record: 1 Show: All Selected Records (0 out of 1160 Selected) Options

Figure 19: Attribute Table

Using the data in the Attribute table **create** an Excel spreadsheet to estimate the population for each Census block. To do this, **copy** the attribute table and **paste** it into Excel (individual columns in the attribute table cannot be copied so it is necessary to copy the entire table into Excel where it can be manipulated). **Copy** the attribute table by selecting all data (**press** *Ctrl-A*) **Right-click** on the left most column and **select** *Copy Selected.* Then **copy** the following columns: *ID* (the Block ID) and *POP2000* (the population of each block) from the recently created Excel sheet and **paste** them into another Excel spreadsheet. Then **create** columns for the number of buildings in the Census block and in the floodplain, the buildings in the Census block but not in the floodplain, and the estimated population living in both the Census block and the floodplain in the new Excel Spreadsheet. The columns of Table 1 show the columns of the spreadsheet with a description of the source of the information in that column.

ID	POP2000	Buildings Included	Buildings Excluded	Estimated Population
Given from Attribute table.	Given from Attribute table.	Found by counting buildings in aerial photos	Found by counting buildings in aerial photos	Equation 2

Table 1: Population Calculator Spreadsheet

Estimating Population

The next step is filling the empty columns in the spreadsheet with data. The column detailing the average household size is calculated by dividing the population of the block by the number of households. To fill in the columns with the number of buildings in the Census block included and excluded from the floodplain, the team used the unclipped Census blocks and floodplain layers over the aerial photos. Figure 20 is an example of a section of the resulting map. The floodplain is shaded with a blue hatch so the aerial photo can still be seen, and the Census blocks are outlined in red.

Figure 20: Census Blocks near a Floodplain

If part of a building is in the floodplain then the entire building was considered to be within the floodplain because FEMA requires all buildings that are partially in a floodplain to have flood insurance. It was unnecessary to count the buildings in a Census block that is completely in or out of a floodplain. For adjusting the population of the Census block, only the ratio given in Equation 1 is important:

$$\frac{BUILDINGS\ INCLUDED}{BUILDINGS\ INCLUDED+BUILDINGS\ EXCLUDED} \qquad (1)$$

If every building in the Census block is in the floodplain, Equation 1 is equal to one. Block 1 in Figure 20 is an example of a Census block with all buildings in the floodplain. For this block, **type** a one in the *Buildings Included* column and a zero in the *Buildings Excluded* column. If the floodplain area in a Census block does not include any buildings, the ratio detailed in Equation 1 is equal to zero. Block 2 in Figure 20 is an example of a Census block with no buildings in the floodplain. In this case, **type** a zero into the *Buildings Included* column and a one in the *Buildings Excluded* column.

If the floodplain area in a Census block includes houses in the flood region and houses that are outside the flood region, **determine** the estimated population by using the ratio in Equation 1. First, **count** the buildings inside the floodplain, and the buildings outside the floodplain for each Census block. **Type** the number of buildings inside the floodplain in the *Buildings Included* column and the number of buildings outside the floodplain in the *Buildings Excluded* column. Block 3 in Figure 20 contains 17 buildings within the floodplain and 4 buildings outside the floodplain. In this case, 17 would be typed into the *Buildings Included* column and 4 would be typed in the *Buildings Excluded* column. Equation 1 is then equal to 17/21, approximately 0.810. This ratio is used to determine the Estimated Population column. To determine the adjusted population of a Census block, Equation 2 was used, which multiplies with the population of the Census block to get Equation 2:

$$\frac{2000POP*BUILDINGS\ INCLUDED}{BUILDINGS\ INCLUDED+BUILDINGS\ EXCLUDED} \qquad (2)$$

Table 2 below gives an example where data that was collected was entered into the Population Calculator Spreadsheet. It demonstrates how to determine the adjusted population in the three different cases; when no buildings in the block are in the floodplain, when a portion of the buildings in the block are in the floodplain, and when all of the buildings in the block are in the floodplain.

ID	POP2000	Buildings Included	Buildings Excluded	Adjusted Population
160	22	0	1	0
285	32	4	10	9
289	106	1	0	106

Table 2: Population Calculator Spreadsheet Example

After the population for all of the Census blocks is adjusted within the floodplain region, **sum** all adjusted Census block populations. **Repeat** this process for each flood risk designation, resulting in a total population estimate for all floodplains.

Step 4: Creating the Population Map

The next step is to add the newly estimated populations to ArcGIS. In ArcGIS, **right click** on the *PRBlocksAE* and **click** on *Data,* then *Export Data*. **Click** *OK*, then a box will open up. If Yes is clicked it will add the exported data to the map as a layer, this is not necessary as PRBlocksAE is already a map layer, so **Click** *No*. This will create all the files associated with this layer, these files are the shapefile (.SHP), PRJ , SBN, SBX, SHX, XML, and the database file (.dbf). When layers are exported they are named Export_Output. By default the files are exported to the Desktop. **Rename** the files PRBlocksAE. Make sure they are all named the same or they will not work properly. **Open** the database file (.dbf) with OpenOffice.

Copy the Estimated Population column into the *POP2000* column of the floodplain's database file and save it. The *PRBlocksAE* layer in ArcGIS now has the estimated population for the AE floodplain region. The next step is to configure it in ArcGIS. **Right-click** on the *PRBlocksAE* layer and **select** *Properties* **click** on the *Symbology* tab as shown in Figure 21.

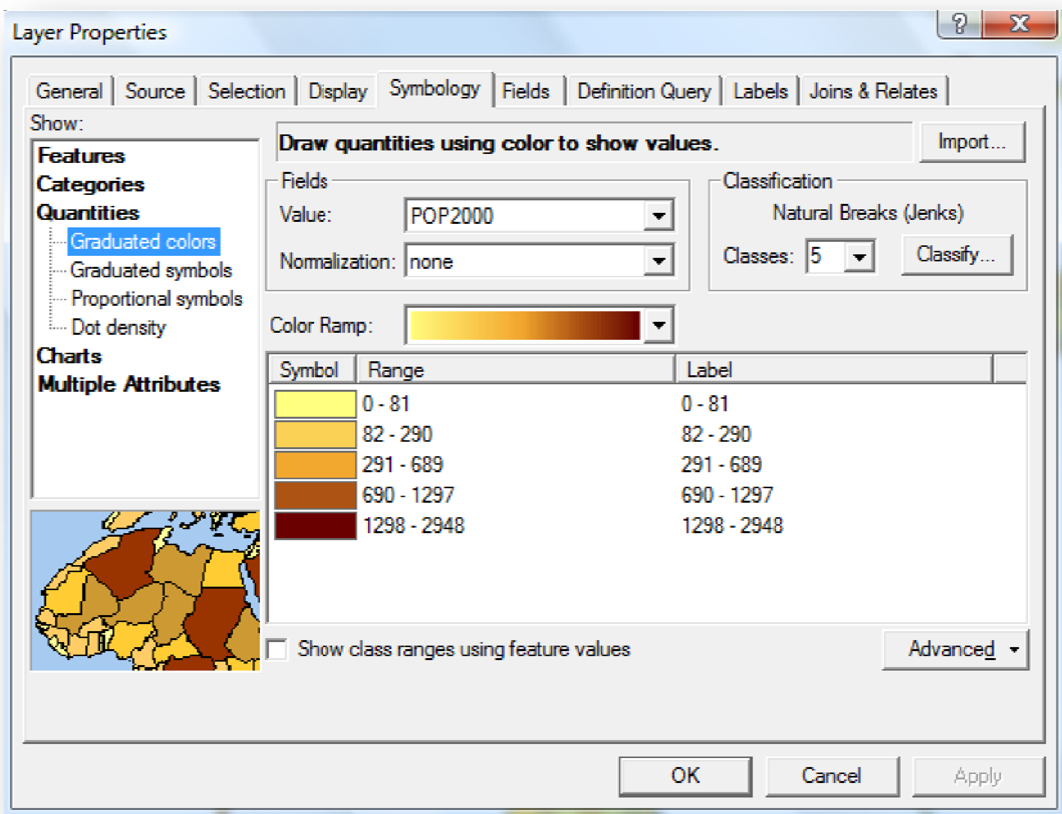


Figure 21: Symbology Menu

This menu is for determining the map's color ramp, number of classes, ranges, labels, value to display, and classification of classes. **Change** the *Fields Value* to *POP2000*. This configures ArcGIS to associate each block on the map with its *POP2000* value. The classification method chosen in this tutorial is Natural Breaks (Jenkins). Select the desired method and **Click** *OK*.

Using ArcGIS to Find Population Sums

To calculate the population of any arbitrary floodplain or section of floodplain, ArcGIS can calculate the sum of the individual populations in a selected area. Before it is possible to select a specific floodplain region, it is necessary to turn off all the layers that do not wished to be included in the calculation. Then **Click** the *Select Features* utility in the *Tools* tool bar and **highlight** an area of blocks.

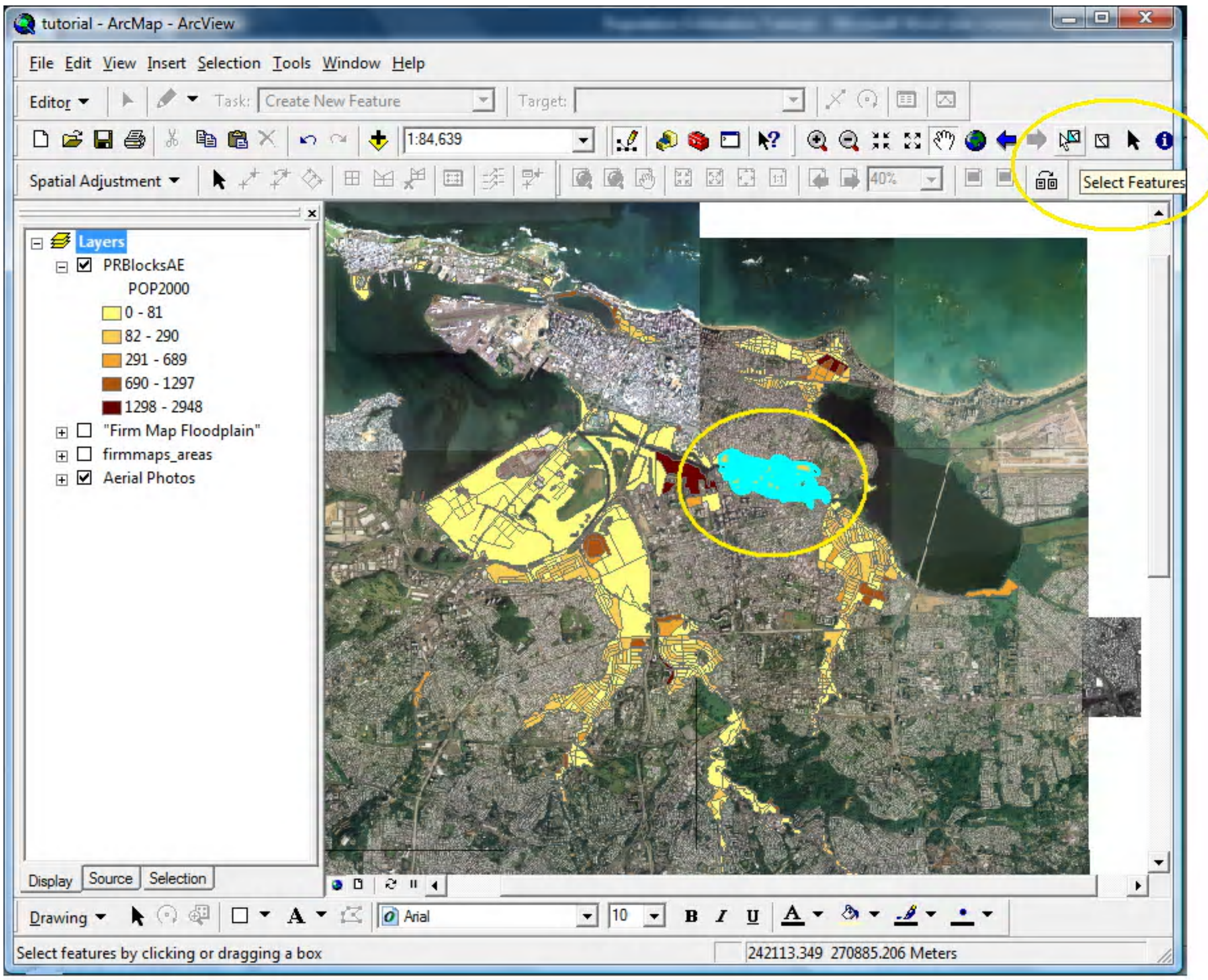


Figure 22 Select Features tool and a Selected Area

Next **pull down** the *Selection* menu and **click** *Statistics*. This opens the menu shown in Figure 23. The *Selection Statistics* tool displays statistics such as the count, minimum, maximum, mean, sum, and standard deviation of the selected blocks. The *count* refers to the number of Census blocks that are selected. The *minimum* is the lowest value that any of the selected blocks contain. The *maximum* refers to the highest value that any of the blocks contain. The *sum* is the sum of all the values of each individual block. The *mean* is the calculated average of the population of all the selected blocks. Lastly, the *standard deviation* displays the standard deviation of the values. The *Selection Statistics* utility can calculate statistics of any layer that has been selected by the *select features* tool. The values that these statistics are using to determine each statistic are decided in the *Field* Pull Down menu. To find the estimated population of the selected area, **select** *POP2000* in the *Field* Pull Down menu. The *sum* is the estimated population of the selected area. The estimated population of the selected area in Figure 22 is determined to be 15369 for the AE flood region, as shown in Figure 23.

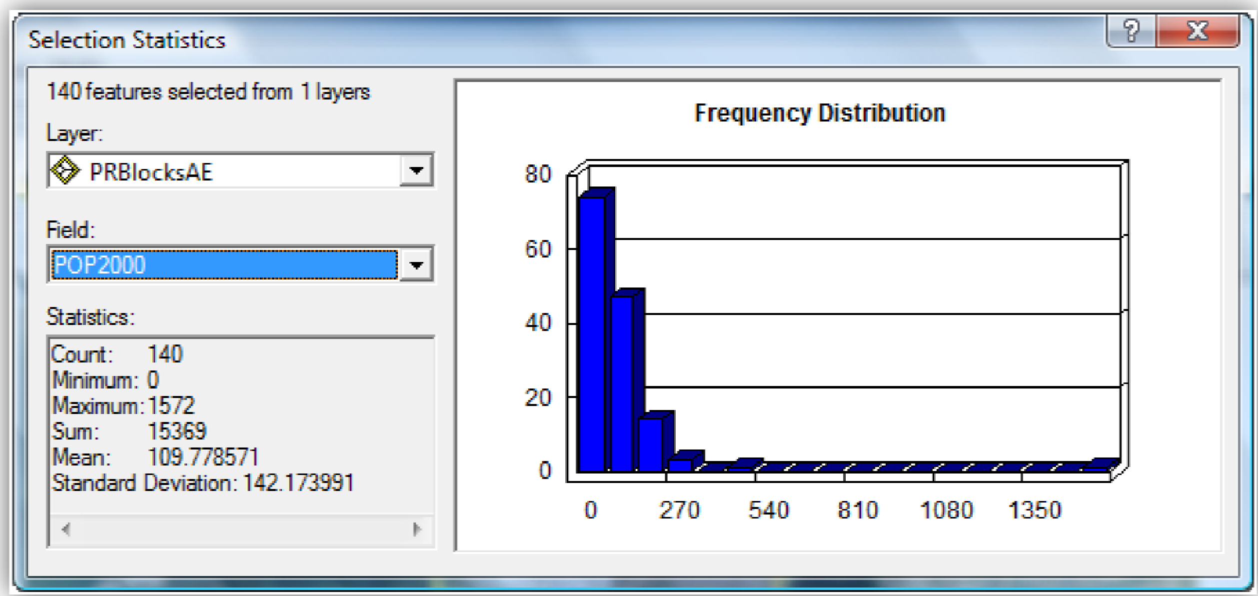


Figure 23 Selection Statistics Menu

Step 5: Layout View

Once the map has been configured it is ready to be formatted using the Layout view. To use Layout view, **click** on *View* and select *Layout View*. This view is used to format the map for printing. This section will explain each step to add a legend, title, scale, and north arrow.

Inserting the Legend

Legends explain the symbology used in a map. To insert a legend, **pull down** the *Insert* menu and **click** on *Legend*. This will bring up the *Legend Wizard*, shown in Figure 24. This wizard provides a step by step guide through the creation of the legend. The wizard automatically adds every item from the layers to the legend. To remove the unwanted items, **select** the item and **click** <. **Repeat** this step to remove all unwanted items. When all unwanted items are removed, **click** *Next*.

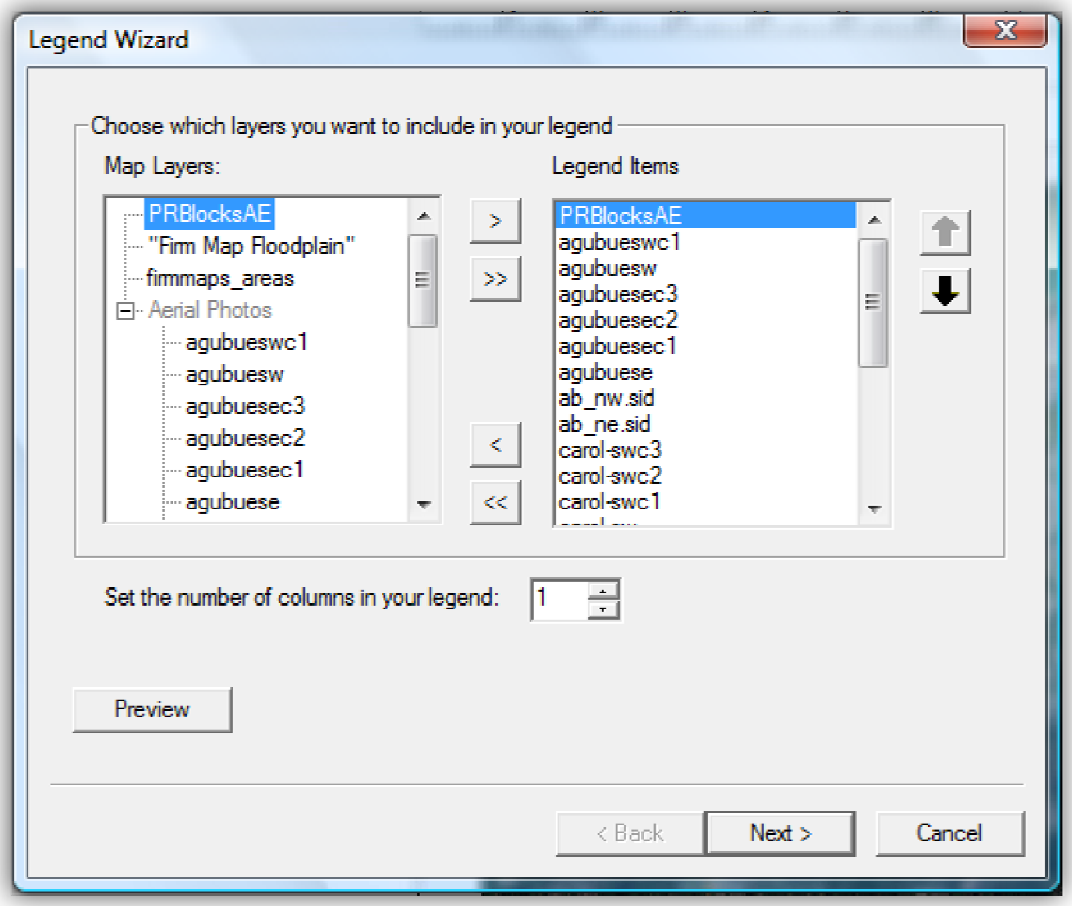


Figure 24 First Window of Legend Wizard

It is possible to change the font, size, and color of the title in this window. **Type** the desired name of the legend, and **click** *Next*.

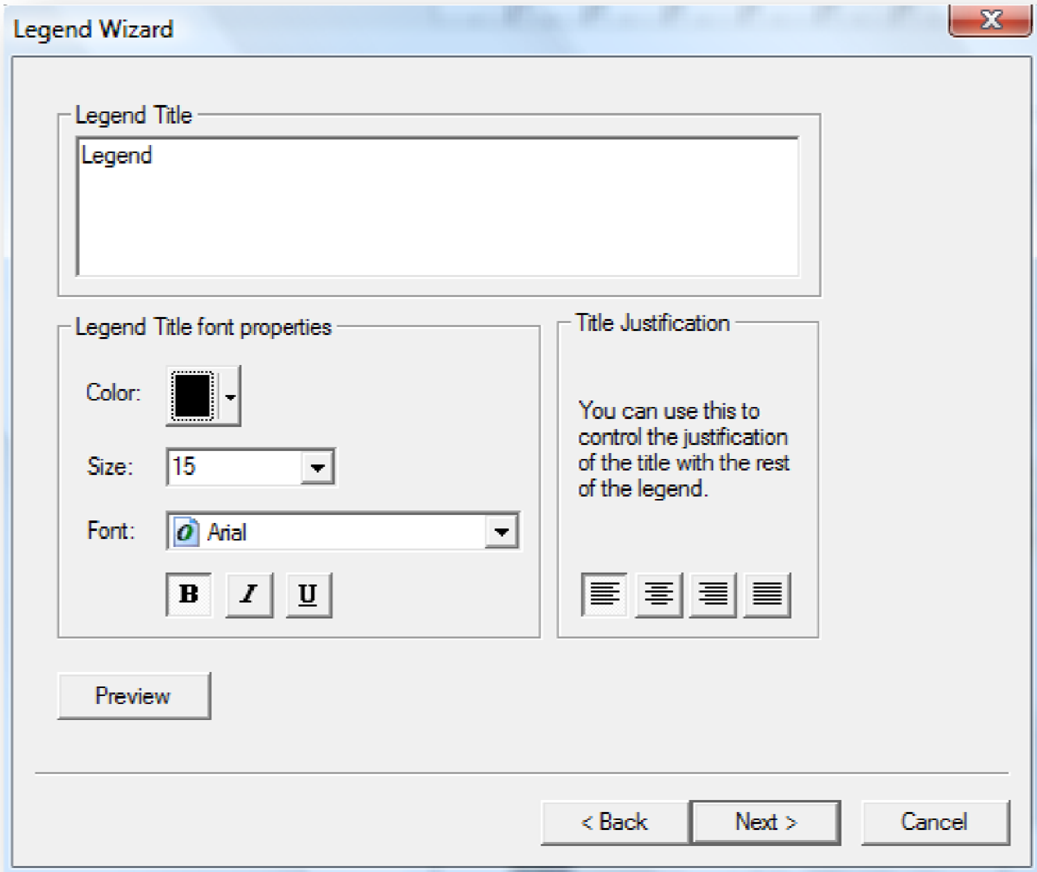


Figure 25 Second Window of Legend Wizard

This window configures the legend frame. **Click** *Next*.

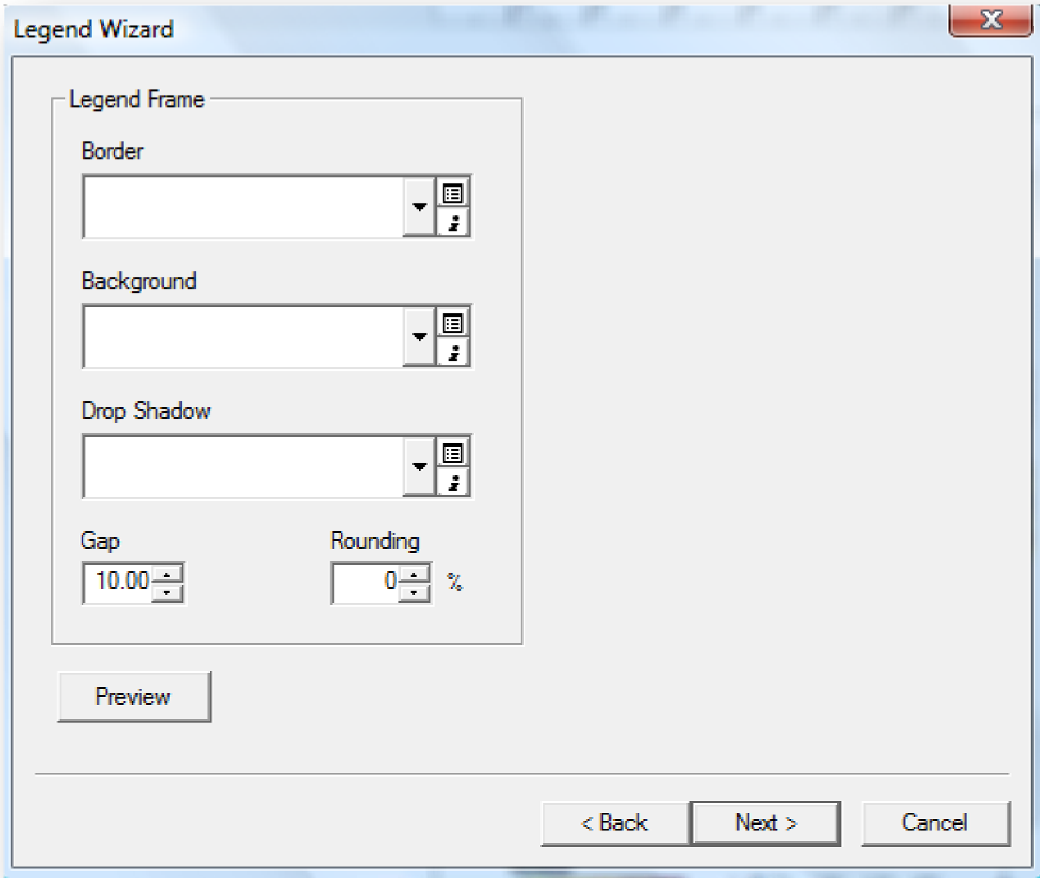


Figure 26 Third Window of Legend Wizard

In this window, the size and shape of the symbol patch used to represent line and polygon features in the legend can be changed. When done, **click** *Next*.

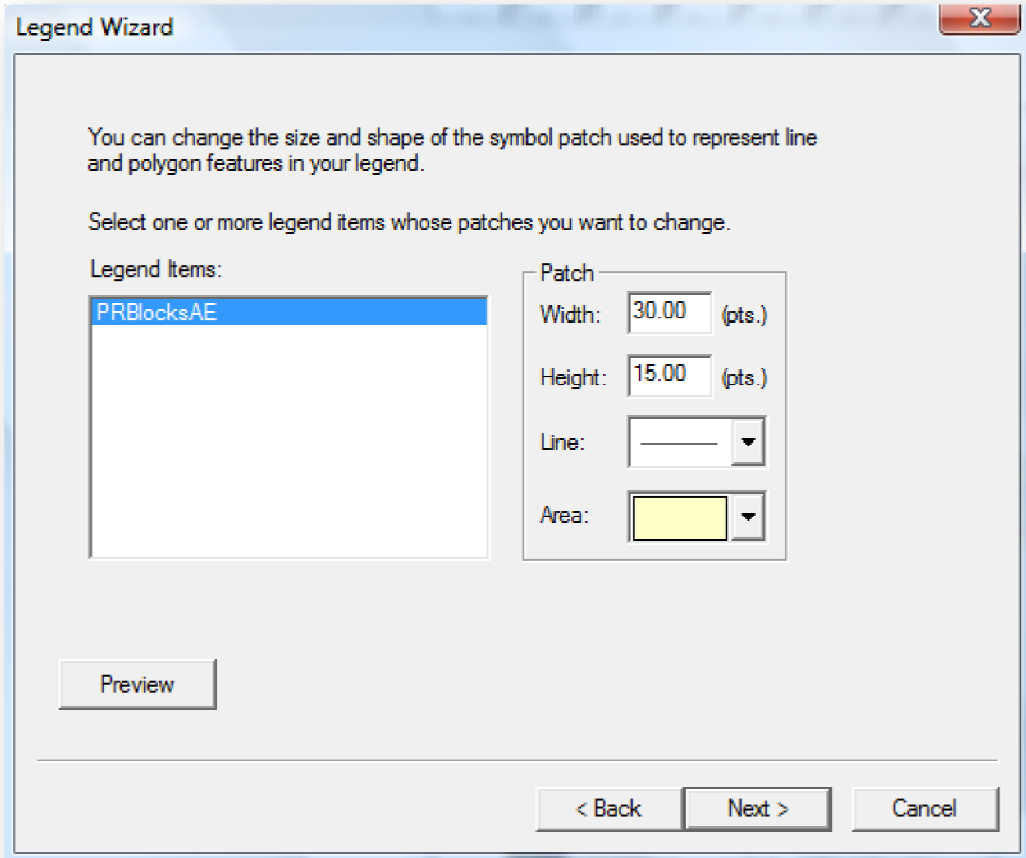


Figure 27 Fourth Window of Legend Wizard

This window sets the spacing between the numbers, symbols, and letters of the legend. **Click** *Finish* after choosing appropriate spacing. To configure the style of the legend, **double click** on the legend object box. This will bring up the *Legend Properties* window. **Click** on the *Items* tab.

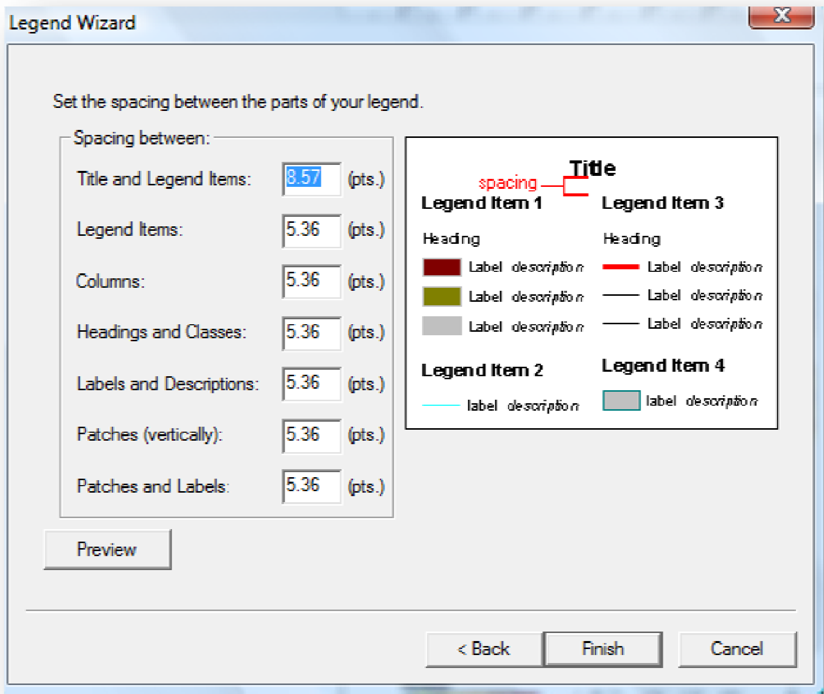


Figure 28 Fifth Window of Legend Wizard

Double click on the legend item in the right column, in this case AE.

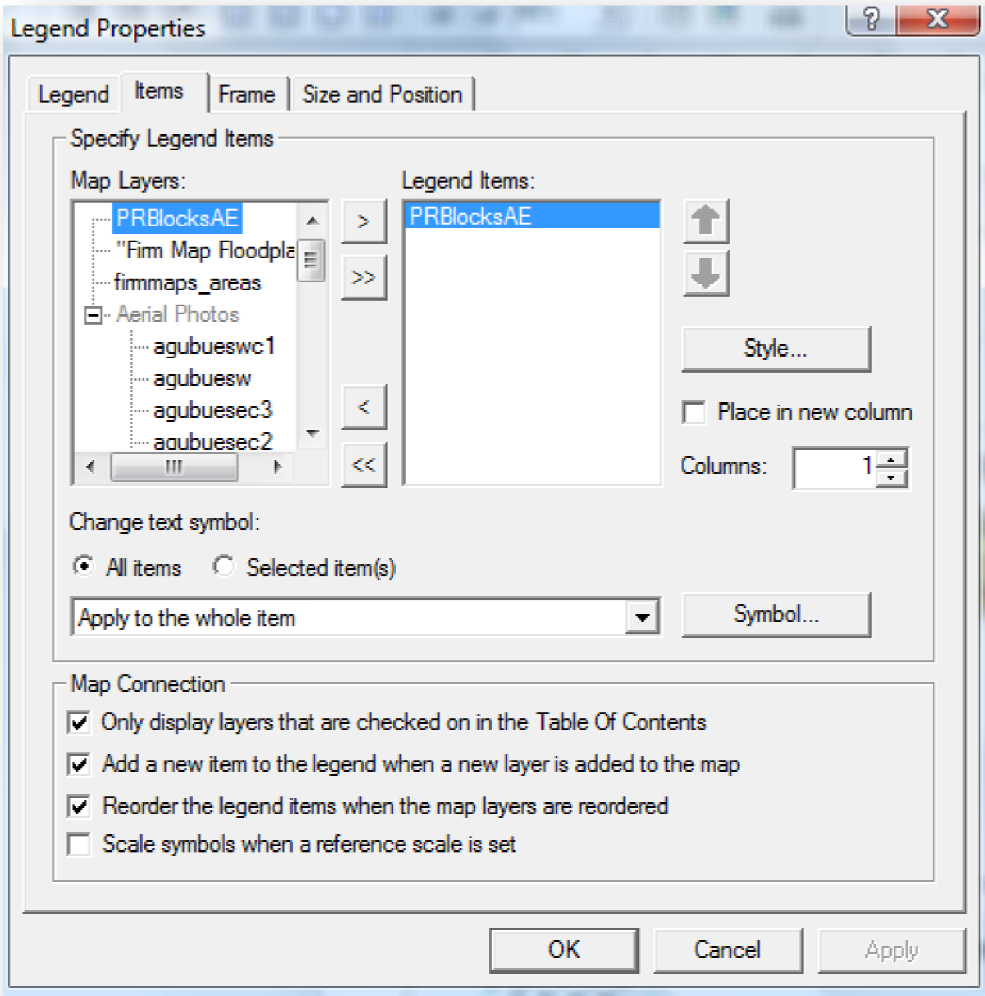


Figure 29 Legend Properties Window

From here it is possible to select many different styles for the legend. This tutorial uses the horizontal bar with heading, labels, and description. Pick the desired style and **click** *OK*.

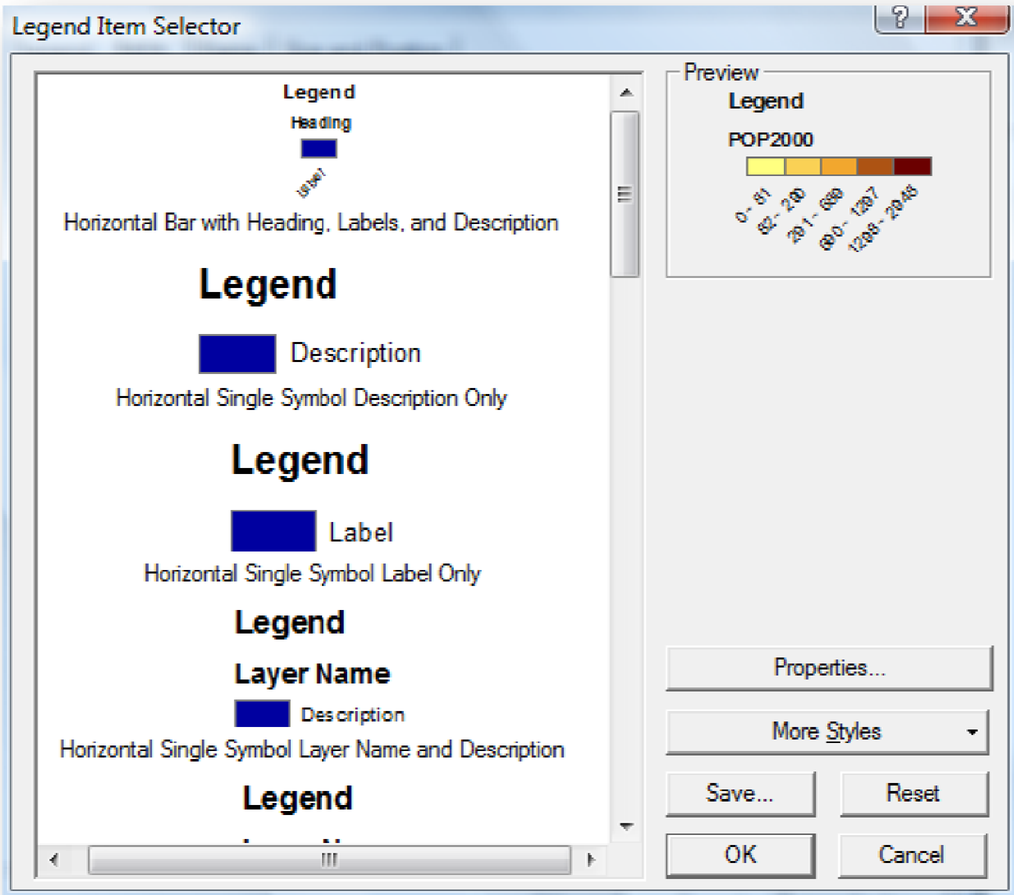


Figure 30: Legend Item Selector

At this point the map should look similar to Figure 31.

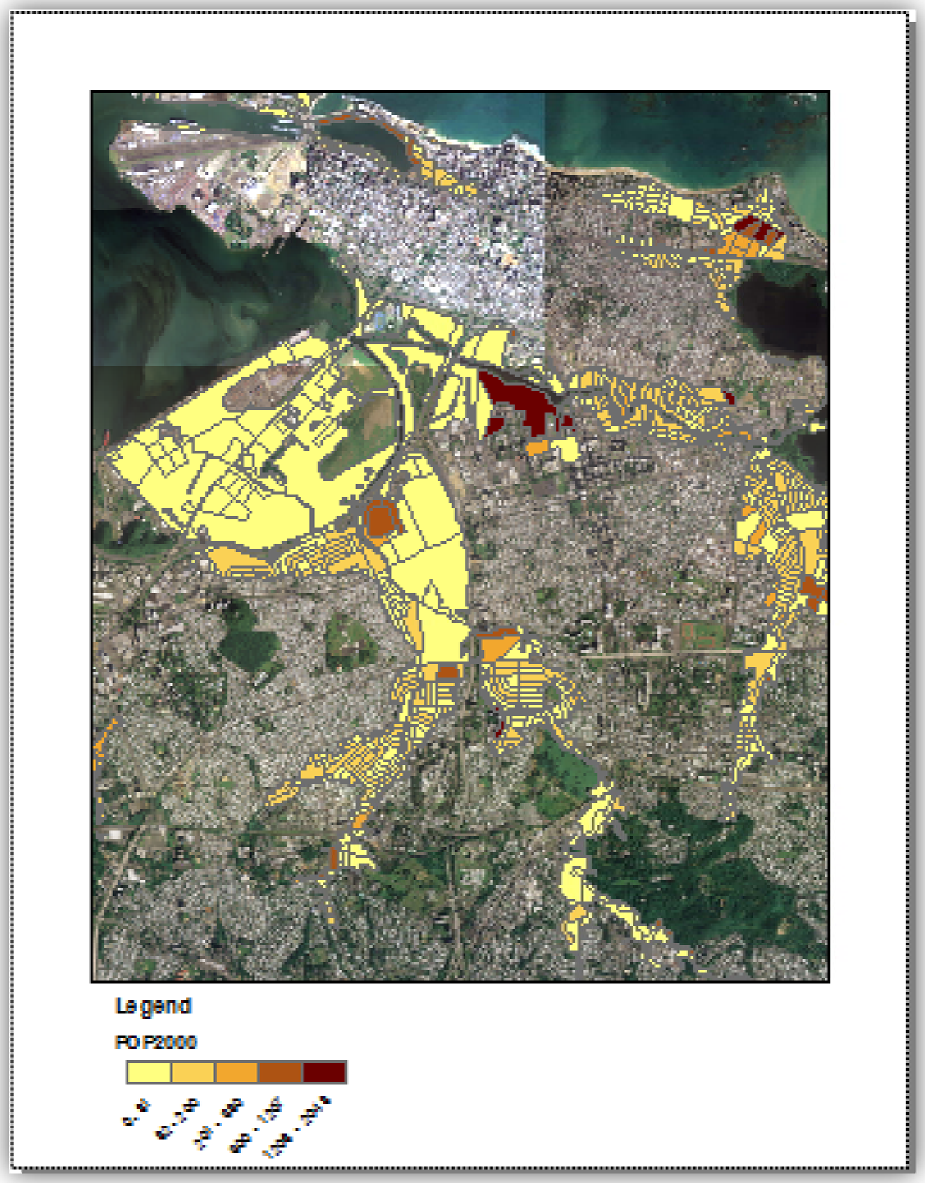


Figure 31: Population Map with Legend

Inserting the Title

Titles are used to describe the region and contents of a map. To add a title **pull down** the *Insert* menu and **click** on the *Title* option, as shown in Figure 32.

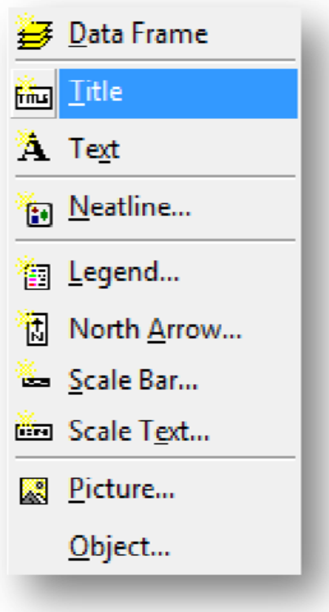


Figure 32: Insert Title

A text box will appear with the project name in it. **Double click** on the *text box* to open up the text properties menu.

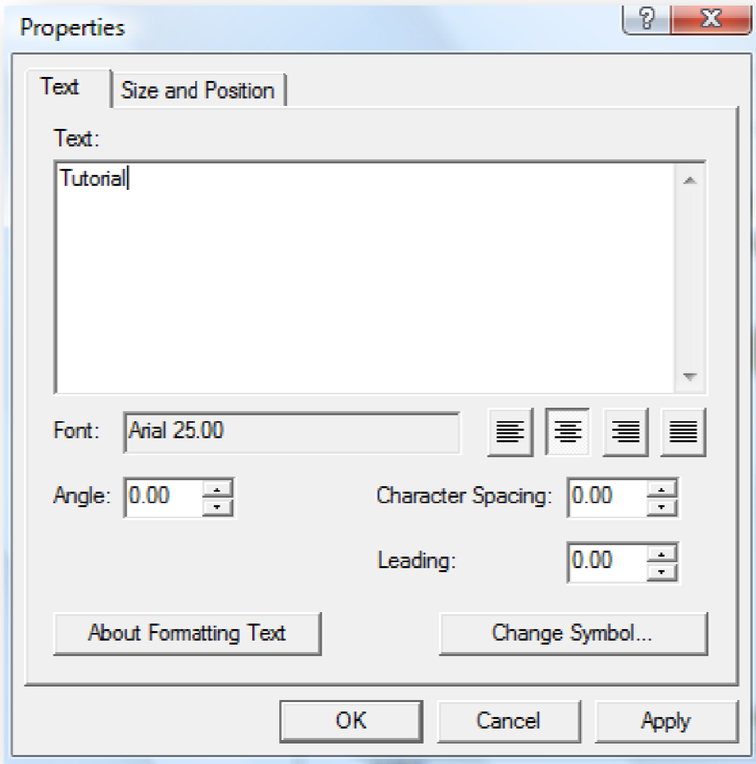


Figure 33 Text Properties Menu

In this menu, text, font, color, and other attributes can be adjusted. After choosing an appropriate title and its attributes, **click** *OK*.

Inserting the Scale Bar

Scale bars are used to relate the distance on the map to the actual distance on the ground. To insert a scale bar **pull down** the *Insert* menu and **click** on *Scale Bar*.

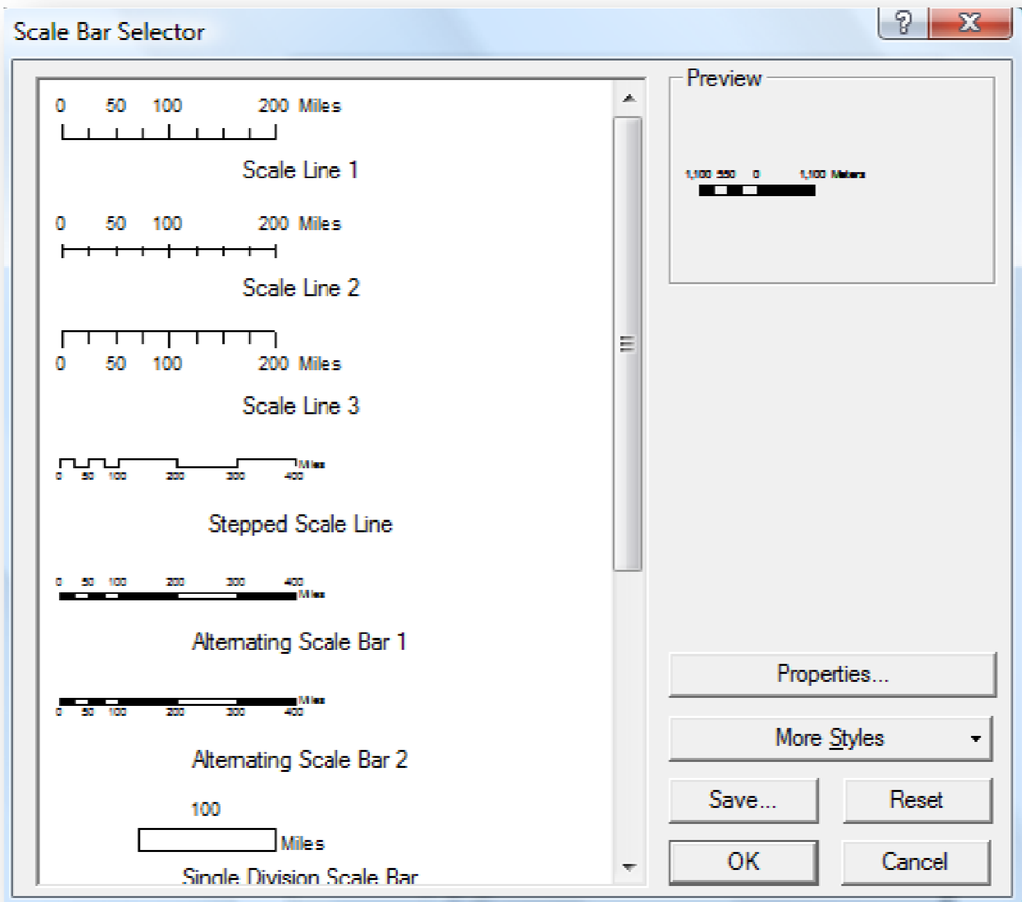


Figure 34: Scale Bar Selector Menu

There are many different styles of scales available in the *Scale Bar Selector* window, shown in Figure 34. **Select** a scale and **click** *OK*.

Inserting the North Arrow

A north arrow identifies the north direction. Although it seems very simple it is crucial to be aware of the orientation of the map. To insert a north arrow, go to **pull down** *Insert* and **click** *North Arrow*. The *North Arrow Selector* menu is displayed in Figure 35. This menu provides a list of different styled north arrows to choose from. Select a north arrow and click ***OK***.

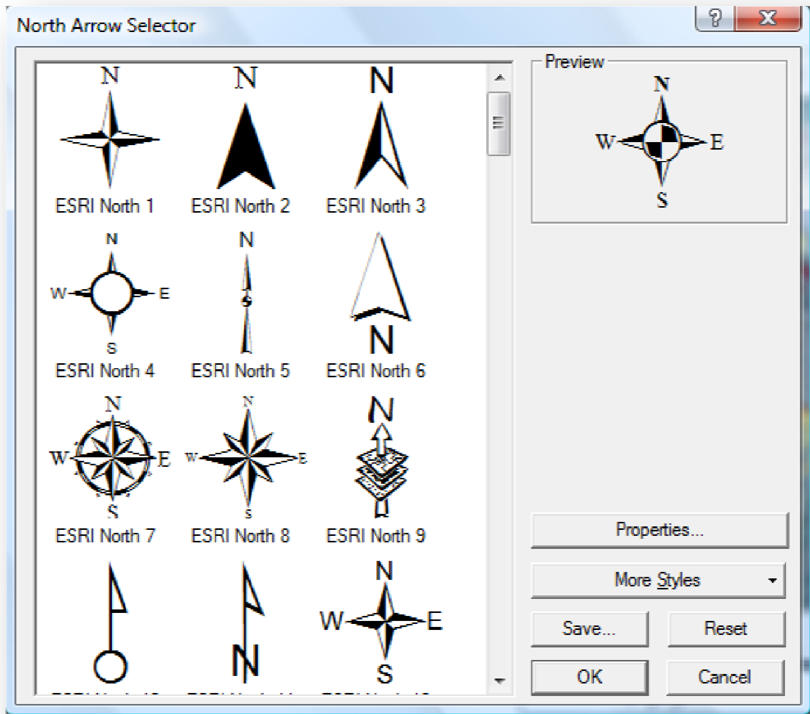


Figure 35: North Arrow Selector Menu

Step 6: Finished Population Map

The last step is to export the map image. **Pull down** the *File* menu and **Select** *Export Map*. **Choose** a file name and a file type. **Click** *Save.* The exported map is shown in Figure 36.

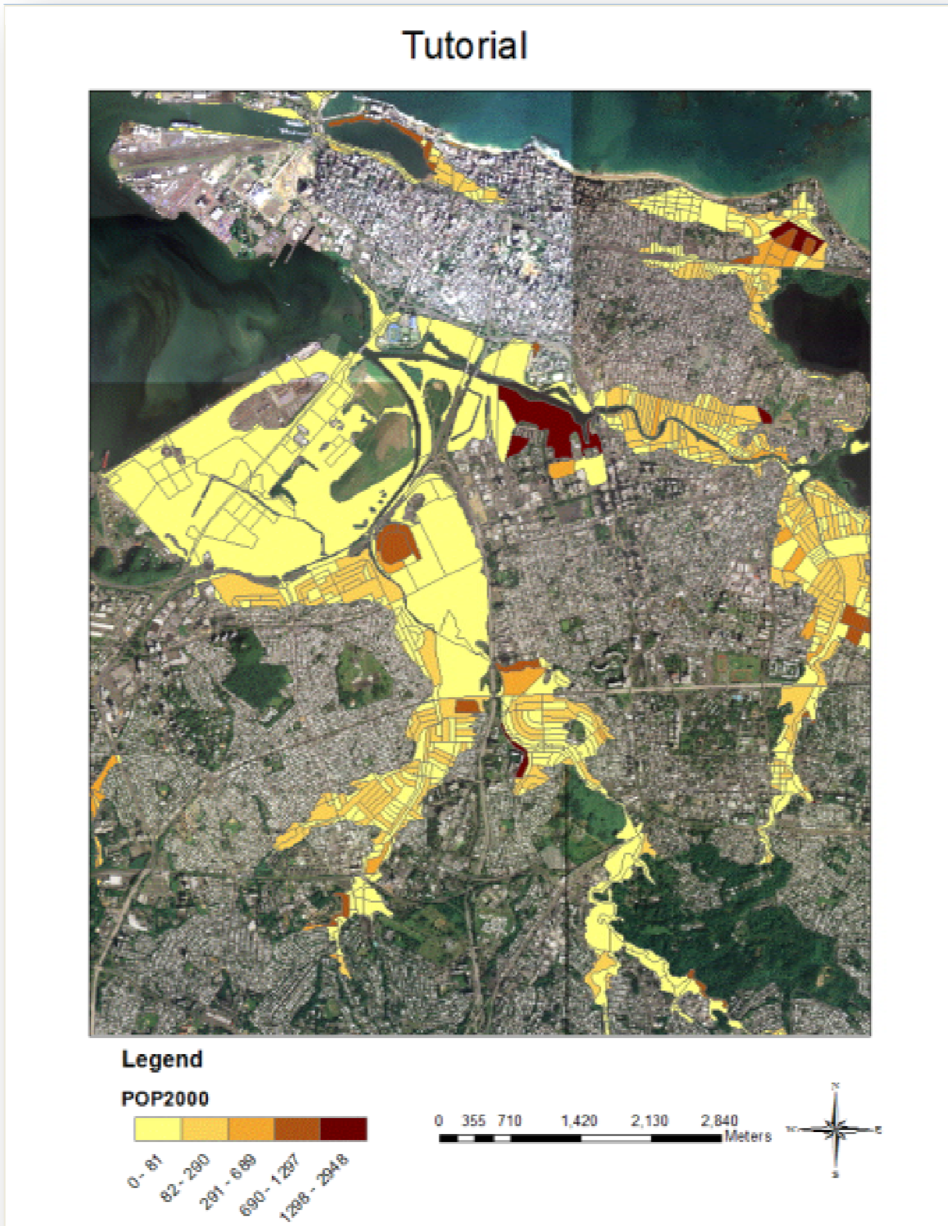


Figure 36: Completed and Exported Map

Figure 36 displays the finalized Population Map of all of the floodplains in San Juan, Puerto Rico.

Conclusion

This tutorial has covered the essentials of creating a population map using ArcGIS. By the end of Step 6 of this tutorial, the user should have attained an estimation of the population residing in the floodplain and a population map illustrating the distribution of population throughout the floodplain.

APPENDIX F: COMPREHENSIVE SURVEY DATA

What is your age?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-15	2	.5	.5	.5
	16-25	21	5.0	5.0	5.5
	26-35	46	11.0	11.0	16.5
	36 or more	349	83.5	83.5	100.0
	Total	418	100.0	100.0	

What is your gender?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	235	56.2	56.2	56.2
	Male	183	43.8	43.8	100.0
	Total	418	100.0	100.0	

How many years have you lived at this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4	105	25.1	25.1	25.1
	5-10	44	10.5	10.5	35.6
	11-15	34	8.1	8.1	43.8
	16 or more	235	56.2	56.2	100.0
	Total	418	100.0	100.0	

Where does the owner of this residence live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I own	264	63.2	63.2	63.2
	In building	81	19.4	19.4	82.5
	Nearby	13	3.1	3.1	85.6
	Another neighborhood	43	10.3	10.3	95.9
	I'm Unsure	17	4.1	4.1	100.0
	Total	418	100.0	100.0	

What is the foundation made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	408	97.6	97.6	97.6
	Wood	10	2.4	2.4	100.0
	Total	418	100.0	100.0	

What is the siding made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wood	34	8.1	8.1	8.1
	Metal	2	.5	.5	8.6
	Cement	381	91.1	91.1	99.8
	Other	1	.2	.2	100.0
	Total	418	100.0	100.0	

Are you aware your house is in an area designated by FEMA as a floodplain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	322	77.0	77.0	77.0
	No	96	23.0	23.0	100.0
	Total	418	100.0	100.0	

What flooding problems affect your community?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid					
	Light Rain	133	31.8	31.8	31.8
	Heavy Rain	207	49.5	49.5	81.3
	Both	52	12.4	12.4	93.8
	No Flooding	25	6.0	6.0	99.8
	No Response	1	.2	.2	100.0
	Total	418	100.0	100.0	

Do you have flood insurance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	121	28.9	28.9	28.9
	No	229	54.8	54.8	83.7
	I don't know	68	16.3	16.3	100.0
	Total	418	100.0	100.0	

How many floods have you experienced while living in this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	140	33.5	33.5	33.5
	1-2	97	23.2	23.2	56.7
	3-4	40	9.6	9.6	66.3
	5 or more	141	33.7	33.7	100.0
	Total	418	100.0	100.0	

How many times have you experienced flood damage to this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	288	68.9	68.9	68.9
	1-2	91	21.8	21.8	90.7
	3-5	24	5.7	5.7	96.4
	6 or more	15	3.6	3.6	100.0
	Total	418	100.0	100.0	

If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-2	330	78.9	78.9	78.9
	3-5	80	19.1	19.1	98.1
	6 or more	8	1.9	1.9	100.0
	Total	418	100.0	100.0	

Have you ever been compensated for damage at this residence? If so, on how many occasions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid					
	Never	344	82.3	82.3	82.3
	Once	55	13.2	13.2	95.5
	2-3 Times	16	3.8	3.8	99.3
	4 or more times	3	.7	.7	100.0
	Total	418	100.0	100.0	

Have you taken measures to prevent flood damage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	146	34.9	34.9	34.9
	No	272	65.1	65.1	100.0
	Total	418	100.0	100.0	

Community

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	University Garden	30	7.2	7.2	7.2
	Reparto Metropolitano	69	16.5	16.5	23.7
	Puerto Nuevo	85	20.3	20.3	44.0
	Barrio Obrero	99	23.7	23.7	67.7
	San Jose	135	32.3	32.3	100.0
	Total	418	100.0	100.0	

APPENDIX G: SURVEY DATA FROM UNIVERSITY GARDENS

What is your age?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-15	1	3.3	3.3	3.3
	26-35	3	10.0	10.0	13.3
	36 or more	26	86.7	86.7	100.0
	Total	30	100.0	100.0	

What is your gender?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	16	53.3	53.3	53.3
	Male	14	46.7	46.7	100.0
	Total	30	100.0	100.0	

How many years have you lived at this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4	9	30.0	30.0	30.0
	5-10	1	3.3	3.3	33.3
	11-15	3	10.0	10.0	43.3
	16 or more	17	56.7	56.7	100.0
	Total	30	100.0	100.0	

Where does the owner of this residence live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I own	20	66.7	66.7	66.7
	In building	4	13.3	13.3	80.0
	Nearby	1	3.3	3.3	83.3
	Another neighborhood	4	13.3	13.3	96.7
	I'm Unsure	1	3.3	3.3	100.0
	Total	30	100.0	100.0	

What is the foundation made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	30	100.0	100.0	100.0

What is the siding made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	30	100.0	100.0	100.0

Are you aware your house is an area designated by FEMA as a floodplain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	28	93.3	93.3	93.3
	No	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

What flooding problems affect your neighborhood?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Light Rain	12	40.0	40.0	40.0
	Heavy Rain	16	53.3	53.3	93.3
	Both	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Do you have any flood insurance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	21	70.0	70.0	70.0
	No	4	13.3	13.3	83.3
	I don't know	5	16.7	16.7	100.0
	Total	30	100.0	100.0	

How many floods have you experienced while living in this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	1	3.3	3.3	3.3
	1-2	23	76.7	76.7	80.0
	3-4	6	20.0	20.0	100.0
	Total	30	100.0	100.0	

If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-2	20	66.7	66.7	66.7
	3-5	10	33.3	33.3	100.0
	Total	30	100.0	100.0	

How many times have you experienced flood damage to this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	12	40.0	40.0	40.0
	1-2	16	53.3	53.3	93.3
	3-5	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

Have you ever been compensated for damage at this residence? If so, on how many occasions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid					
	Never	16	53.3	53.3	53.3
	Once	8	26.7	26.7	80.0
	2-3 Times	6	20.0	20.0	100.0
	Total	30	100.0	100.0	

Have you taken measures to prevent flood damage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	15	50.0	50.0	50.0
	No	15	50.0	50.0	100.0
	Total	30	100.0	100.0	

APPENDIX H: SURVEY DATA FROM REPARTO METROPOLITANO

What is your age?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-15	1	1.4	1.4	1.4
	16-25	1	1.4	1.4	2.9
	26-35	8	11.6	11.6	14.5
	36 or mo	59	85.5	85.5	100.0
	Total	69	100.0	100.0	

What is your gender?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	40	58.0	58.0	58.0
	Male	29	42.0	42.0	100.0
	Total	69	100.0	100.0	

How many years have you lived at this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4	20	29.0	29.0	29.0
	11-15	5	7.2	7.2	36.2
	16 or more	36	52.2	52.2	88.4
	5-10	8	11.6	11.6	100.0
	Total	69	100.0	100.0	

Where does the owner of this residence live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Another	8	11.6	11.6	11.6
	I own	49	71.0	71.0	82.6
	I'm Unsure	2	2.9	2.9	85.5
	In building	10	14.5	14.5	100.0
	Total	69	100.0	100.0	

What is the foundation made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	69	100.0	100.0	100.0

What is the siding made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	68	98.6	98.6	98.6
	Other	1	1.4	1.4	100.0
	Total	69	100.0	100.0	

Are you aware your house is an area designated by FEMA as a floodplain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	13	18.8	18.8	18.8
	Yes	56	81.2	81.2	100.0
	Total	69	100.0	100.0	

What flooding problems affect your neighborhood?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid					
	Both	27	39.1	39.1	39.1
	Heavy Rain	33	47.8	47.8	87.0
	Light Rain	9	13.0	13.0	100.0
	Total	69	100.0	100.0	

Do you have any flood insurance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I don't	16	23.2	23.2	23.2
	No	25	36.2	36.2	59.4
	Yes	28	40.6	40.6	100.0
	Total	69	100.0	100.0	

How many floods have you experienced while living in this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	27	39.1	39.1	39.1
	1-2	7	10.1	10.1	49.3
	3-4	8	11.6	11.6	60.9
	5 or more	27	39.1	39.1	100.0
	Total	69	100.0	100.0	

If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-2	59	85.5	85.5	85.5
	3-5	10	14.5	14.5	100.0
	Total	69	100.0	100.0	

How many times have you experienced flood damage to this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	55	79.7	79.7	79.7
	1-2	8	11.6	11.6	91.3
	3-5	5	7.2	7.2	98.6
	6 or more	1	1.4	1.4	100.0
	Total	69	100.0	100.0	

Have you ever been compensated for damage at this residence? If so, on how many occasions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid					
	Never	68	98.6	98.6	98.6
	Once	1	1.4	1.4	100.0
	Total	69	100.0	100.0	

Have you taken measures to prevent flood damage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	44	63.8	63.8	63.8
	Yes	25	36.2	36.2	100.0
	Total	69	100.0	100.0	

APPENDIX I: SURVEY DATA FROM PUERTO NUEVO

What is your age?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	16-25	3	3.5	3.5	3.5
	26-35	12	14.1	14.1	17.6
	36 or more	70	82.4	82.4	100.0
	Total	85	100.0	100.0	

What is your gender?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	41	48.2	48.2	48.2
	Male	44	51.8	51.8	100.0
	Total	85	100.0	100.0	

How many years have you lived at this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4	24	28.2	28.2	28.2
	11-15	6	7.1	7.1	35.3
	16 or more	43	50.6	50.6	85.9
	5-10	12	14.1	14.1	100.0
	Total	85	100.0	100.0	

Where does the owner of this residence live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Another	9	10.6	10.6	10.6
	I own	53	62.4	62.4	72.9
	I'm Unsure	1	1.2	1.2	74.1
	In build	18	21.2	21.2	95.3
	Nearby	4	4.7	4.7	100.0
	Total	85	100.0	100.0	

What is the foundation made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	85	100.0	100.0	100.0

What is the siding made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	85	100.0	100.0	100.0

Are you aware your house is in an area designated by FEMA as a floodplain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	15	17.6	17.6	17.6
	Yes	70	82.4	82.4	100.0
	Total	85	100.0	100.0	

What flooding problems affect your neighborhood?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Both	10	11.8	11.8	11.8
	Heavy Rain	34	40.0	40.0	51.8
	Light Rain	40	47.1	47.1	98.8
	No Response	1	1.2	1.2	100.0
	Total	85	100.0	100.0	

Do you have any flood insurance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I don't know	13	15.3	15.3	15.3
	No	36	42.4	42.4	57.6
	Yes	36	42.4	42.4	100.0
	Total	85	100.0	100.0	

How many floods have you experienced while living in this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	24	28.2	28.2	28.2
	1-2	25	29.4	29.4	57.6
	3-4	12	14.1	14.1	71.8
	5 or more	24	28.2	28.2	100.0
	Total	85	100.0	100.0	

If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-2	51	60.0	60.0	60.0
	3-5	29	34.1	34.1	94.1
	6 or more	5	5.9	5.9	100.0
	Total	85	100.0	100.0	

How many times have you experienced flood damage to this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	36	42.4	42.4	42.4
	1-2	32	37.6	37.6	80.0
	3-5	10	11.8	11.8	91.8
	6 or more	7	8.2	8.2	100.0
	Total	85	100.0	100.0	

Have you ever been compensated for damage at this residence? If so, on how many occasions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2-3 Times	4	4.7	4.7	4.7
	4 or more	3	3.5	3.5	8.2
	Never	50	58.8	58.8	67.1
	Once	28	32.9	32.9	100.0
	Total	85	100.0	100.0	

Have you taken measures to prevent flood damage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	47	55.3	55.3	55.3
	Yes	38	44.7	44.7	100.0
	Total	85	100.0	100.0	

APPENDIX J: SURVEY DATA FROM BARRIO OBRERO

What is your age?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	16-25	8	8.1	8.1	8.1
	26-35	5	5.1	5.1	13.1
	36 or more	86	86.9	86.9	100.0
	Total	99	100.0	100.0	

What is your gender?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	53	53.5	53.5	53.5
	Male	46	46.5	46.5	100.0
	Total	99	100.0	100.0	

How many years have you lived at this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4	26	26.3	26.3	26.3
	11-15	10	10.1	10.1	36.4
	16 or more	57	57.6	57.6	93.9
	5-10	6	6.1	6.1	100.0
	Total	99	100.0	100.0	

Where does the owner of this residence live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Another	10	10.1	10.1	10.1
	I own	53	53.5	53.5	63.6
	I'm Unsure	9	9.1	9.1	72.7
	In build	22	22.2	22.2	94.9
	Nearby	5	5.1	5.1	100.0
	Total	99	100.0	100.0	

What is the foundation made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	94	94.9	94.9	94.9
	Wood	5	5.1	5.1	100.0
	Total	99	100.0	100.0	

What is the siding made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	75	75.8	75.8	75.8
	Metal	2	2.0	2.0	77.8
	Wood	22	22.2	22.2	100.0
	Total	99	100.0	100.0	

Are you aware your house is in an area designated by FEMA as a floodplain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	35	35.4	35.4	35.4
	Yes	64	64.6	64.6	100.0
	Total	99	100.0	100.0	

What flooding problems affect your neighborhood?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Both	16	16.2	16.2	16.2
	Heavy Rain	40	40.4	40.4	56.6
	Light Rain	29	29.3	29.3	85.9
	No Flood	14	14.1	14.1	100.0
	Total	99	100.0	100.0	

Do you have any flood insurance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I don't know	15	15.2	15.2	15.2
	No	77	77.8	77.8	92.9
	Yes	7	7.1	7.1	100.0
	Total	99	100.0	100.0	

How many floods have you experienced while living in this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	28	28.3	28.3	28.3
	1-2	27	27.3	27.3	55.6
	3-4	4	4.0	4.0	59.6
	5 or more	40	40.4	40.4	100.0
	Total	99	100.0	100.0	

If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-2	83	83.8	83.8	83.8
	3-5	16	16.2	16.2	100.0
	Total	99	100.0	100.0	

How many times have you experienced flood damage to this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	71	71.7	71.7	71.7
	1-2	23	23.2	23.2	94.9
	3-5	2	2.0	2.0	97.0
	6 or more	3	3.0	3.0	100.0
	Total	99	100.0	100.0	

Have you ever been compensated for damage at this residence? If so, on how many occasions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2-3 Times	2	2.0	2.0	2.0
	Never	88	88.9	88.9	90.9
	Once	9	9.1	9.1	100.0
	Total	99	100.0	100.0	

Have you taken measures to prevent flood damage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	63	63.6	63.6	63.6
	Yes	36	36.4	36.4	100.0
	Total	99	100.0	100.0	

APPENDIX K: SURVEY DATA FROM SAN JOSÉ

What is your age?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	16-25	9	6.7	6.7	6.7
	26-35	18	13.3	13.3	20.0
	36 or more	108	80.0	80.0	100.0
	Total	135	100.0	100.0	

What is your gender?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	85	63.0	63.0	63.0
	Male	50	37.0	37.0	100.0
	Total	135	100.0	100.0	

How many years have you lived at this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-4	26	19.3	19.3	19.3
	11-15	10	7.4	7.4	26.7
	16 or more	82	60.7	60.7	87.4
	5-10	17	12.6	12.6	100.0
	Total	135	100.0	100.0	

Where does the owner of this residence live?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Another	12	8.9	8.9	8.9
	I own	89	65.9	65.9	74.8
	I'm Unsure	4	3.0	3.0	77.8
	In building	27	20.0	20.0	97.8
	Nearby	3	2.2	2.2	100.0
	Total	135	100.0	100.0	

What is the foundation made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	130	96.3	96.3	96.3
	Wood	5	3.7	3.7	100.0
	Total	135	100.0	100.0	

What is the siding made of?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cement	123	91.1	91.1	91.1
	Wood	12	8.9	8.9	100.0
	Total	135	100.0	100.0	

Are you aware your house is in an area designated by FEMA as a floodplain?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	31	23.0	23.0	23.0
	Yes	104	77.0	77.0	100.0
	Total	135	100.0	100.0	

What flooding problems affect your neighborhood?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Both	1	.7	.7	.7
	Heavy Rain	84	62.2	62.2	63.0
	Light Rain	43	31.9	31.9	94.8
	No Flood	7	5.2	5.2	100.0
	Total	135	100.0	100.0	

Do you have any flood insurance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I don't know	19	14.1	14.1	14.1
	No	87	64.4	64.4	78.5
	Yes	29	21.5	21.5	100.0
	Total	135	100.0	100.0	

How many floods have you experienced while living in this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	60	44.4	44.4	44.4
	1-2	15	11.1	11.1	55.6
	3-4	10	7.4	7.4	63.0
	5 or more	50	37.0	37.0	100.0
	Total	135	100.0	100.0	

If you have ever experienced a flood at this residence, what was the highest flood you experienced (in feet)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-2	117	86.7	86.7	86.7
	3-5	15	11.1	11.1	97.8
	6 or more	3	2.2	2.2	100.0
	Total	135	100.0	100.0	

How many times have you experienced flood damage to this residence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	114	84.4	84.4	84.4
	1-2	12	8.9	8.9	93.3
	3-5	5	3.7	3.7	97.0
	6 or more	4	3.0	3.0	100.0
	Total	135	100.0	100.0	

Have you ever been compensated for damage at this residence? If so, on how many occasions?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2-3 Times	4	3.0	3.0	3.0
	Never	122	90.4	90.4	93.3
	Once	9	6.7	6.7	100.0
	Total	135	100.0	100.0	

Have you taken measures to prevent flood damage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	103	76.3	76.3	76.3
	Yes	32	23.7	23.7	100.0
	Total	135	100.0	100.0	