Creating a Geodatabase and Web-GIS Map to Visualize Drone Legislation in the State of Maryland

by

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A Thesis Presented to the
Faculty of the USC Graduate School
University of Southern California
In Partial Fulfillment of the
Requirements for the Degree
Master of Science
(Geographic Information Science and Technology)

December 2016

Dedication

I would like to dedicate this thesis to my family and friends who have supported me through the creation of this thesis, especially my wife, Wawa; my sister, Meagan; the computer guru, Aaron; and my mother, father, and step-mom.

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List of Abbreviations

CA	California
D.C.	District of Columbia
DJI	Da-Jiang Innovations Science and Technology Co.
DOI	Department of the Interior
ERD	Entity Relationship Diagram
FAA	Federal Aviation Administration
FK	Foreign Key
GIS	Geographic Information System
MD	Maryland
MDGA	Maryland General Assembly
MSSQLS	Microsoft's Sequel Server
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
PHP	Personal Home Page
PK	Primary Key
TXT	Text File
UAV	Unmanned Aerial Vehicle
USA	The United States of America

Abstract

Drones are unmanned aerial vehicles that are remotely controlled. They range in size from under one pound to several hundred pounds (Perlman 2016). This thesis addresses drones classified for consumer use, which the Federal Aviation Administration (FAA) defines as drones between 0.55 to 55 lbs. (FAA 2016e). Since consumer drones have been available for purchase in greater numbers than ever before, legislation related to no-fly zones needs to be centrally organized (Perlman 2016). This can be done through the creation of a geodatabase and web-GIS map, which will allow for visualization of drone use areas. The study area for this thesis is the state of Maryland, which was chosen because it contains every type of FAA no-fly zone and has not passed any drone use sub-national rules; this allows for the current FAA regulations to be studied and improvements reccommended where necessary. This web-GIS map will allow state government policymakers, drone hobbyists, and other members of the public to see where it is appropriate to use drones in Maryland. Visualizing and making drone use data universally available will reduce accidental drone trespassing and will guide users to where drone fly-zones areas are located. To achieve this goal, a geodatabase was designed with five feature classes to show the required data and steps necessary to catalogue and display drone use data properly. A web-GIS map was then constructed that allows users to differentiate between types of fly zones and obtain details regarding the permissibility of drone flight in these zones. This geodatabase, coupled with the web-GIS map of appropriate and inappropriate drone use fly-zones, provides an effective model for other states to use to create their own drone use maps.

Chapter 1 Introduction

Drones, also known as unmanned aerial vehicles (UAVs), have a multitude of uses. Drones are perhaps best known for their application in times of war and for various types of surveillance. They also are used for scientific, logistical, and recreational purposes. According to Dr. Kaufui Vincent Wong, drones are one of the most important tools that will be used for peaceful scientific, commercial, and hobby uses in the next century (Wong 2015). Privacy and safety issues related to drones, however, have made their function a topic of major debate. This debate has only intensified with the advent of drones being readily available for consumer/recreational use. This is why it is important to develop both a well-organized geodatabase and a drone use web-GIS map. This web-GIS map will help hobbyists, the general public, and government policymakers become educated on the acceptable areas for drone use under existing regulations. This geodatabase and web-GIS map will support policymakers in developing and communicating rules for drone safety and also will provide hobbyists with a tool to locate lawful areas to practice flying their drones. This chapter introduces the concept of what a consumer drone is, current consumer drone use regulations and legislation in the U.S., information on the study area, an introduction to geodatabases and web-GIS maps, the motivation for creating this project, the goals of the thesis, and a guide to the remainder of this thesis' structure.

1.1 What Are Drones?

According to the FAA, consumer drones are defined as UAVs: Vehicles that are not piloted like airplanes; that range in weight from 0.55 to 55 lbs.; and are controlled remotely by their users for recreational use (FAA 2016e). Consumer drones are also limited in flight height to no higher than 400 feet from a building or the ground (FAA 2016f). These hobby drones are not to be confused with their larger counterparts, also known as commercial or military use drones, which have caused great concern about potential misuse. There are many types of drones that are in the consumer market; some common ones are shown in Figure 1. With the ability to buy drones over the internet, consumer drone use has been steadily increasing (Perlman 2016). A typical consumer drone has four motors that allow it to fly anywhere from 15 minutes to more than one hour. These drones usually also have a camera and a remote control for operation. That being said, there are many variants of consumer drones that have a wide range of additional components and abilities. With a better understanding of what consumer drones and their capabilities are, the general public should perceive them as less of a threat.

Figure 1 Common consumer drone brands available in the U.S. (Gabriel 2014).

1.2 How Are Drones Different from Airplanes?

It is critical to understand how drones differ from airplanes both in terms of their form and their regulations. Drones, are operated remotely from the ground via remote control, whereas planes have on-board pilots. Drones are also regulated differently than airplanes. Airplanes require numerous licenses and annual testing to operate them safely (FAA 2015a). Drones require registration and are regulated by the FAA, but do not require licensing for recreational use. Airplanes must obtain approval from air traffic control stations for their flight plans and observe all posted FAA no-fly zones through which they are not cleared to fly. Drone no-fly zones surround sensitive areas and areas of high volume, low flying aircraft. Without these no-fly zones, which are explained in further detail in Chapter 3, accidents involving planes would be more likely to occur (Messing 2016).

1.3 The History of Consumer Drone Regulation

Drones have been around for much longer than the average person may realize. For military purposes, drones have been around since the mid-1800s (CITE 2002). Consumer drones have been available to the public since the early 2000s. It was not until 2008, however, that the FAA specifically enacted any official regulation regarding their use (Anderson 2008). Before this time, because drones were classified as model aircraft, drone management fell under the regulation of the *Model Aircraft Advisory Circular of 1981* (FAA 2014).

In 2012, the FAA established regulations regarding appropriate and inappropriate use of drones in American airspace pursuant to the authority granted by Congress in the *FAA Modernization and Reform Act of 2012* (49 U.S.C. sec. 40101). This act stipulates most of the no-fly zone areas used in the geodatabase and web-GIS map created for this thesis. This act also dictates that only the FAA can make regulations regarding drone use because drones are used in the atmosphere of the U.S., which falls under the FAA's jurisdiction (49 U.S.C. sec. 40101). The act does make mention of several areas in which state governments may petition to make laws with clearance from the FAA. State governments may issue laws concerning drone use for privacy-related issues, hunting regulations, and law enforcement use (49 U.S.C. sec. 40101).

Since the FAA Modernization and Reform Act of 2012 was enacted, it has undergone some amendments; specifically, additional no-fly zones were added to the legislation. These additions came in 2015 and 2016, as several other laws were passed for classifying consumer and commercial use drones. The major additions to the legislation stated that all consumer and commercial drones need to be registered and that consumer drones were classified as being for recreational use, as well as weighing between 0.55 lbs. and 55 lbs. (FAA 2016e). The most recent significant set of federal regulations regarding drone rights and usage was released in June of 2016.

1.4 Study Area

The study area for this thesis project is the state of Maryland, shown in Figure 2. It was chosen because it borders Washington, D.C. and contains every type of no-fly zone site currently enumerated by the FAA. These sites include sensitive government locations that drone regulation hopes to protect, such as military bases, federal government institutions, national parks, marine reserves, airports and many other vital infrastructures. Another reason that Maryland was chosen is that it has not passed any drone legislation, unlike other states; Virginia, for example, has 21 pieces of legislation promulgated by non-federal authorities (Auvsi 2016). No state law governs consumer drone use in Maryland. The next proposed deadline for drone use regulation is in 2018

(MDGA 2015). For all of these reasons, Maryland is an ideal place to study where drone use is currently both prohibited and permitted.

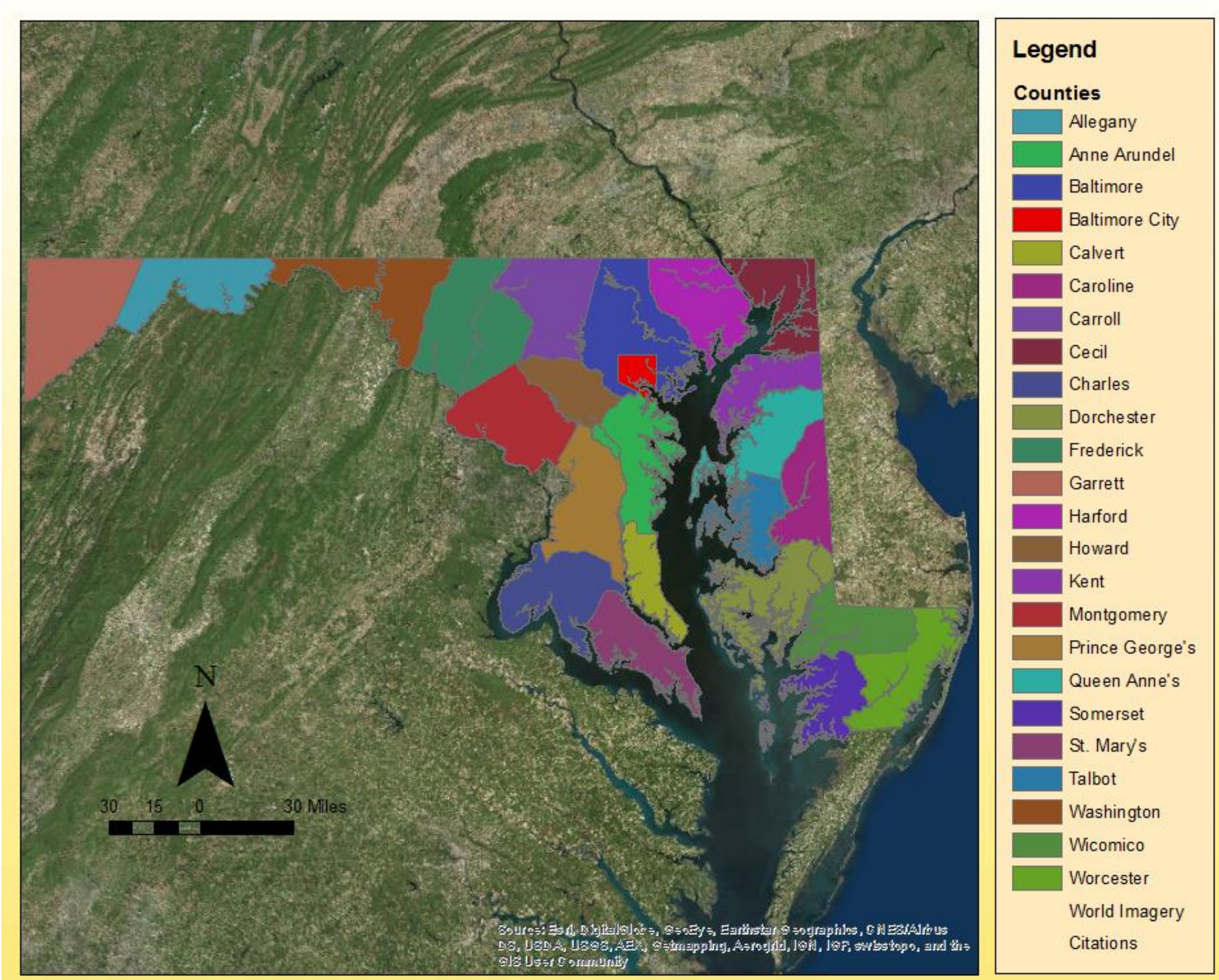

Figure 2 The State of Maryland, by county.

The reason that Maryland was chosen for the site of study is that the state's lack of major legislation will further empower this thesis to demonstrate to the state's policymakers where further drone use legislation is needed. It is important to note that the drone no-fly zones being mapped for this thesis originate in Maryland. They do not include Maryland's bordering states' no-fly zones that may cross over into Maryland's jurisdiction, with one exception in Virginia, which will be discussed later.

1.5 Motivation

The motivating force behind creating both a geodatabase and web-GIS map of areas of appropriate and inappropriate drone use in Maryland was to enable government policymakers to better inform the public about drone use legislation as of June 21^{st}, 2016. The organization and visualization of drone use fly zones will benefit society by not only showing them where drone use is appropriate but also by keeping them informed of the current laws and regulations in place governing drone use. Links to all current federal and state regulations and legislation related to drone use are included on the web-GIS site. By keeping everyone informed, accidental drone trespassing incidents will be reduced, and dialogue between government policymakers, drone hobbyists, and the general public on drone-related privacy and safety issues will be facilitated. Since privacy-related fears are paramount to many people, being informed on current drone use policies and being able to contact government representatives regarding drone use is important (Litchman et al. 2015; Pasztor and Emshwiller 2012; Rosenzweig et al. 2012; Schreiber and Ostiari 2014). The GIS map created for this thesis has been made available to the public by posting it online as a web-GIS map with the intent of advancing the discussion on drone use by having contact information for the federal and state entities responsible for drone use legislation and regulation, as well as drone use clubs that promote safe drone use. Finally, the models of both the geodatabase and web-GIS map described in this thesis can be used by other states for free in the hope that they will build their own geodatabases and web-GIS maps to keep the general public and drone hobbyists informed of the current drone laws in their states.

1.5.1 Drone Regulation Concerns

Drone regulation is a medium through which the public and affected parties, such as the commercial airline industry, can ensure that recreational drones are being used in a manner safe for all. The general public is mainly concerned with privacy issues related to drone video, photographic, and eavesdropping abilities (Cavoukian 2012). Maintaining strong drone privacy regulations is critical to easing the concerns of the general public and to prevent widespread abuses of privacy. This field is relatively new and is constantly evolving. States continue to pass laws and regulations to limit drone use by law enforcement agencies and to prevent trespassing by private parties on private land (AUVSI 2016). Besides the concerns of the general public on privacy, another group that is concerned with drone regulation is pilots and the airplane industry (Whitlock 2015). Drones pose a serious threat to airplane safety. If an airplane collides with a drone, it has the potential to crash the commercial aircraft. Stricter regulations are continuing to be developed - now there is a movement to have built in smart software to prevent drones from flying into high volume aircraft traffic areas (Cheesman 2016).

1.6 Goals of the Thesis

Drone use is becoming an important topic both in government and in society. This thesis project provides both the government and its citizens access to the same visualizations for areas appropriate and inappropriate for drone use within the state of Maryland, where strict legislation does not yet exist. By doing this, both the general public and the government will be able to discuss the next steps for drone legislation within Maryland that both parties would like to see.

The final goal of this thesis was to design an effective drone use geodatabase and interactive web-GIS map of the state of Maryland; and, in doing so, to inform and to support policymakers in developing and communicating rules for drone safety to the general public. The success of this goal was measured by having website visitors take an optional survey attached to the website to rank the information they had before and after visiting the website on areas of appropriate and inappropriate drone use in Maryland.

1.7 Thesis Structure

The remainder of the thesis is broken up into four chapters. Chapter Two discusses other work on GIS and drone use research, as well as both the state and the federal legislation and regulation. This thesis builds on all of the aforementioned topics to create a drone use geodatabase and web-GIS map. Chapter Three outlines the data and steps used to create and to replicate this drone use geodatabase and web-GIS map. Chapter Four discusses the results of creating the drone use geodatabase and how its success was measured. Chapter Five reviews what was accomplished and offers some suggestions for future work.

Chapter 2 Related Work

Understanding federal and state laws on drone use is one of the challenges affecting the general public, including drone hobbyists. Directing them to where it is appropriate to fly drones is intrinsically related to the aforementioned regulations, which are often hard to locate and difficult to interpret. In the following sections on drone use web-GIS mapping, drone use cellular applications, and geodatabase design, the context for the design of an effective geodatabase and web-GIS map to help policymakers convey drone safety rules to the general public in Maryland are described.

2.1 What is a Web-GIS?

A web-GIS map is a GIS map that is accessible from the Internet through a number of outlets, like application-specific GIS software and web-hosting platforms (i.e. arcgis.com). A web-GIS map can be shared as a partial or full data download on GIS platforms, viewed on websites with built-in map plug-ins, and/ or used as a reference picture. A web-GIS map was chosen as the vehicle to deliver the final geodatabase map because it identifies areas of both appropriate and inappropriate drone use in the State of Maryland, and because these maps reach a larger audience than other formats. These maps allow users to interact with the data that they contain. Some drone no-fly zones can be temporarily extended or permanently closed; this data cannot be conveyed in a 2D paper map effectively. The interactive web-GIS map created for this thesis is further explained in both Chapters 3 and 4, and is accessible through http://dreamhost.com.

2.2 Web-GIS Mapping

Web-GIS maps are GIS maps that are created and uploaded onto a website to tell a story through interactive elements, combined within the web-map itself, to reach a wider audience (Fu and Sun 2010). There are several different platforms that allow researchers to create web-GIS content and share it with a broader audience, such as ArcGIS Online 10.31, MapBOX, and other private hosting sites. *Drones Flying Free 2016* contributors Paul Schneider, Ron Behrendt and Cody Benkelman, mention the importance of using web-GIS to convey their findings to a broader audience. They state that it is more effective than a simple paper map (Schneider, Behrendt and Benkelman 2016). The FAA and BBC both reported the use of temporary no-fly zones around Super Bowl 50, when the no-fly zone for drones was extended to 32 miles around Levis Stadium, but did not visualize it on the web (FAA 2016c; BBC 2016). By adding the temporal element of temporary no-fly zones to this report, not only will this geodatabase and web-GIS map be improved upon, but also it will make hobbyists aware of unusual extended no-fly zone buffers when they are trying to locate drone use areas.

2.3 Drone Web-GIS Mapping

No-fly zone web-GIS maps are currently available for aircraft and are being developed for drones. The federal government, private institutions, and individuals all benefit from having accurate and up-to-date fly zone maps. The FAA has created a free no-fly zone map for drones through a private company called MapBOX. This map was a simpler version of the B4UFLY application map and was previously available for online viewing but has now been taken down (FAA 2016a). Two companies at the forefront of this are the Chinese drone manufacturer, Da-

Jiang Innovations Science and Technology Co. (DJI), and the drone analysis company, AIRMAP. In the following two subsections, an analysis of both the positive and the negative elements of DJI's and AIRMAP's web-GIS drone maps as of May 2016 is offered. In doing so, the final web-GIS map created for this thesis project was developed by taking away positive elements from each company's respective web-GIS map design, as well as by noting elements that could be improved or omitted in this thesis' final drone no-fly zone web-GIS map.

2.3.1 AIRMAP's Web-GIS Platform

AIRMAP is a company that offers for purchase drone maps for governments and private companies. They also host a detailed web-GIS map for drone users that has many layers of data that can be switched on and off (shown in Figure 3). This web-map has detailed descriptions of the classification of each data layer that will be emulated in the geodatabase and web-map for this thesis. AIRMAP has the most up-to-date web-GIS map of the web-maps surveyed. It is constantly updating its map to make sure it displays the most accurate visualization of drone use laws. The drawbacks for AIRMAP are that it does not have a cellular standalone application for users, and it requires a lot of reading to understand some of the terminology that they chose in their display of no-fly zones. Another issue found with AIRMAP is that it does not specify how the no-fly zone buffers were created; be it by polygon centroids or polygon boundaries, it is not clear. In this thesis project's map, names/terms were coupled with straightforward symbols to reduce user confusion.

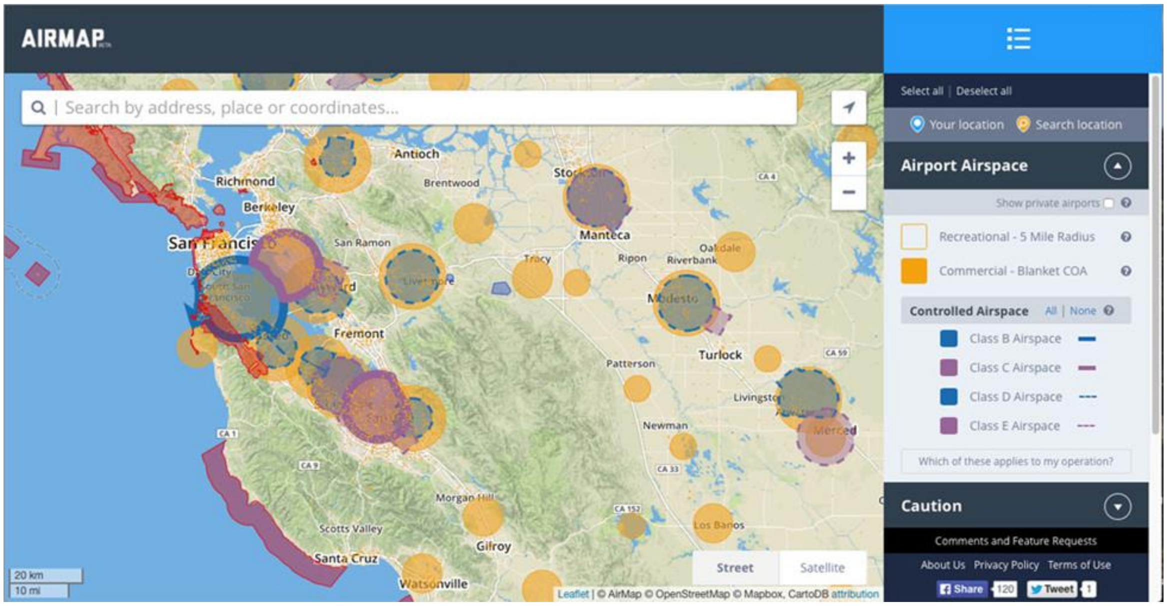

Figure 3 AIRMAP's web-GIS platform showing the no-fly zones around San Francisco, California (http://media.directionsmedia.net/directionsmag/channels/articles/03-nodronesairmap.jpg).

2.3.2 DJI's Web-GIS Platform

The Chinese drone manufacturer DJI has created a simple drone no-fly zone map, shown in Figure 4, which includes only major airports and stadiums. The obvious drawback is that it omits many other sources that would alter no-fly zones, such as military bases, national parks, and local airports (DJI 2016a). According to *Fortune* writer Benjamin Snyder, DJI is one of the largest manufacturers of consumer use drones in North America (Snyder 2015). Even though DJI notes that its maps contain insufficient data to locate every no-fly zone, they insist that their drones have built-in no-fly zone devices, which are common in high end drones. These devices prevent drones from taking off while in a no-fly zone and also from entering a no-fly zone (DJIa 2016). This project's drone use map for the state of Maryland improved upon DJI's lack of data by incorporating the missing data in the company's web-GIS map, such as military bases, local airports, helipads, and college stadiums. This additional data will give drone users a better understanding of where drone use is prohibited.

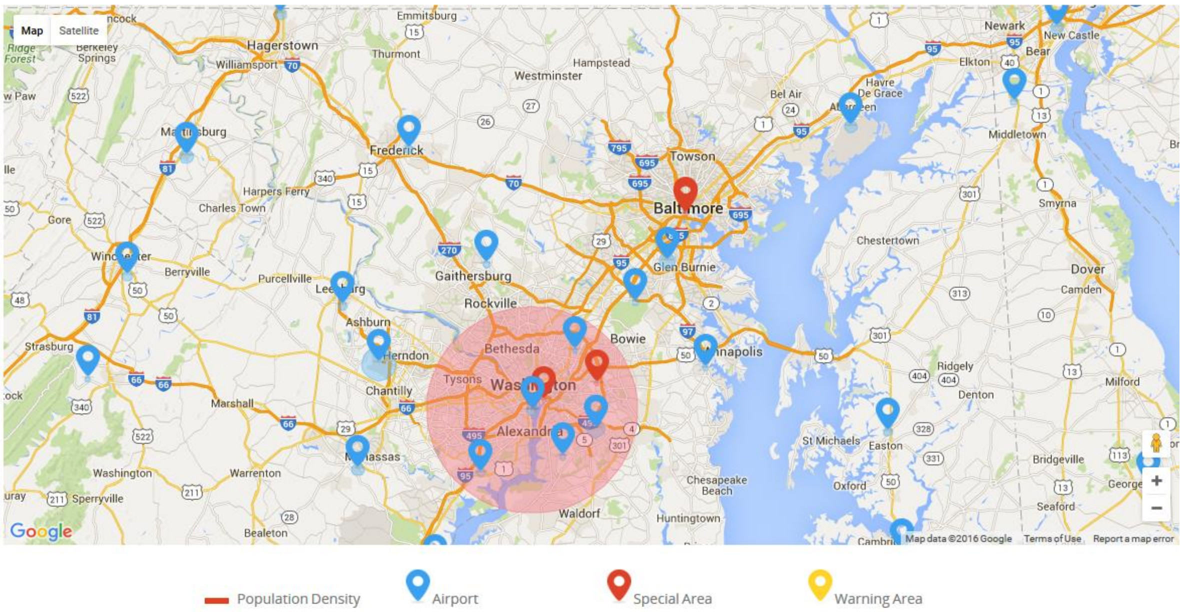

Figure 4 A view of the no-fly zones around the state of Maryland according to DJI (http://www.dji.com/fly-safe/category-mc?www=v1).

2.4 Drone Mapping Applications

Besides the creation of web-GIS online mapping sites for hobbyists to view, many organizations are developing or have developed drone mapping applications available on portable cellular devices. Three of the most popular applications on Apple's iOS operating system are the FAA's B4UFLY, Analytica's Hover, and AIRMAP. In the following subsections, these three cellular data applications are dissected to show each application's strengths and weaknesses.

2.4.1 B4UFLY

The B4UFLY cellular data application started out as an interactive web-GIS map created as the result of a partnership between the company MapBOX and the FAA. At the end of 2015, this web-GIS was removed and the application became available for free download on smart phones and similar portable technology devices. B4UFLY has multiple functions and abilities that increase its ease of use. The main functions of B4UFLY allow users to access a no-fly zone map of their chosen area, shown in Figure 5; plan their drone outing, and provide the user with both permanent and temporary no-fly zones in the areas they may be planning to visit. B4UFLY also lists current day temporary no-fly zones, airports, and national parks for the entire U.S. (FAA 2016a). One of the drawbacks of using B4UFLY is that it requires a cellular data or a Wi-Fi link function, and it is not user-friendly when entering some data on the planner portion of the application. This thesis project's web-map endeavored to make a simpler interface, thereby creating a more accessible web-GIS map for the general public to view.

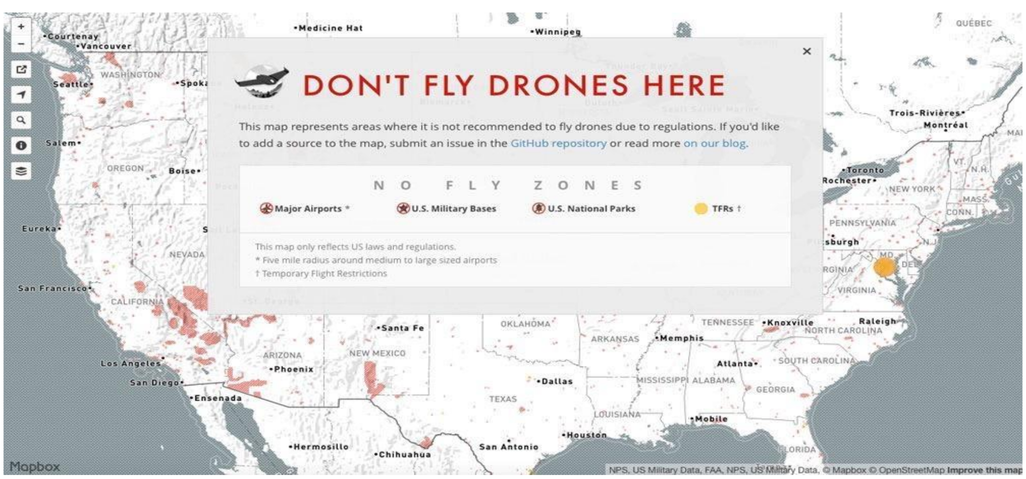

Figure 5 The FAA's B4UFLY application's map of the U.S. with a legend indicating drone no-fly zone types (http://media.directionsmedia.net/directionsmag/channels/articles/01-nodronessite.jpg).

2.4.2 Hover

Hover was created by the company Analytica. It comes with a variety of features that the FAA's B4UFLY application does not have. Hover comes with the standard trip planner seen in the FAA's B4UFLY app, but goes a step further by adding multiple new functions that allow drone users to fully understand the areas in which they wish to fly their drones. Some of these features are shown in Figure 6; they include weather and meteorological data, flight recordings, and a drone newsfeed system that provides users with current drone headlines (Analytica 2015). All of these features are customizable to some degree, allowing users to manipulate what data is used and how it can be viewed.

The only negative issue that can be seen with Hover is that it does not have a legend and has different colored buffers without explanation. Whether these colors mean anything is not stated and could cause potential confusion for users, as seen in Figure 6. The web-map produced for this thesis contains detailed legends identifying different types of no-fly zones to help users fully understand the map and its information.

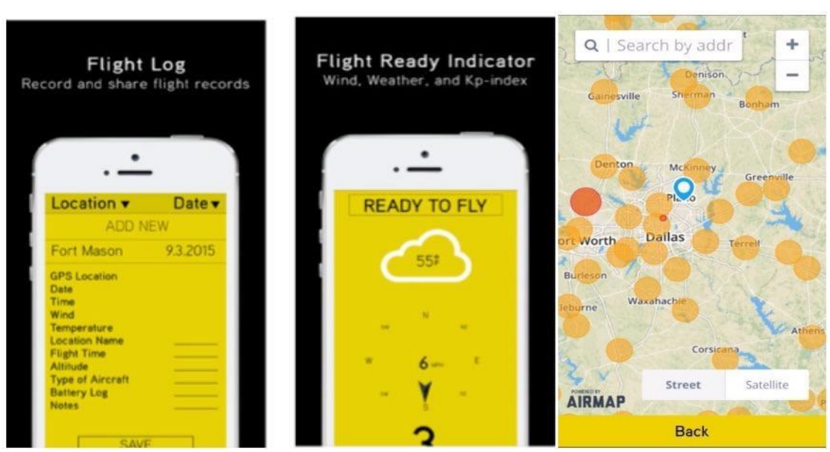

Figure 6 Three of the features offered to drone users by the cellular application Hover; Flight logging, weather data, and a drone no-fly zone web-GIS map (http://media.directionsmedia.net/directionsmag/channels/articles/hover-01.jpg).

2.5 What is a Geodatabase?

A geodatabase is a file storage system that effectively organizes and catalogues GIS data in one place (Baldridge 2012). A geodatabase was needed for this thesis because, by designing one, other people interested in creating a geodatabase of drone use legislation for other states can take this geodatabase and use it as a template for their work, thereby further helping to clarify drone use rules and regulations. Creating an effective geodatabase has several steps: (1) Determining what data is needed; (2) specifying the relationships and interactions in the data by creating an entity relationship diagram (ERD); and (3) arranging the data into a final geodatabase.

The first step in creating a geodatabase was to ascertain what data were needed for the database and then to remove the redundancies in the data. For this thesis, the data types are no-fly zones, temporary restricted no-fly zones, as well as state, county, and parcel data. These data categories came in varying file types, tables, points, lines, and polygon data. The data were all stored in one geodatabase. An example of an ERD can be seen in Chapter 3 of this thesis. After the relationships have been ascertained, a geodatabase should be tested to make sure everything works correctly in a GIS mapping environment. This can be seen in Chapter 4 of this thesis.

2.6 Geodatabase Design

Designing an effective geodatabase and creating drone use regulation maps for every state in America is an important step in allowing seamless transitions for hobbyists when flying near state borders. Kahn (2016) noted that the largest problem that many researchers and the general public have when using government maps is that the federal, state, county, and city level governments often use different terms for the same thing. The geodatabase for this project will be improved upon by looking at the best elements of Kahn's thesis as well as other geodatabase designs from Microsoft's (2016) guide to geodatabase design, and Esri author Michael Zeiler's (2010) geodatabase design guide to allow every state government to make a web-GIS map to guide the general public and drone hobbyists to appropriate drone fly zones.

2.6.1 Kahn's Sinkhole Database Design

Kahn (2016) took the best attribute design elements from multiple states and combined them into one comprehensive geodatabase to categorize sinkhole events, allowing researchers to study them more efficiently. Kahn also suggested that a web-GIS map would be an effective vehicle to allow the general public and researchers to access this database more easily. Kahn's inclusion and simplification of numerous geodatabase attributes used by multiple state governments into one geodatabase with common attributes was emulated for this thesis project as well to reduce the complicated nature of the geodatabase to make it simple, easy to follow, and easy to replicate.

2.6.2 Microsoft's Guide to Geodatabase Design

Microsoft (2016) published a guide on designing databases for Microsoft Access, which is easy to understand and was used as a guide to clarify the basics of database design. Microsoft breaks their database design process down into eight steps; for every two steps, it has a goal that should be accomplished by that time in the geodatabase design process (Microsoft 2016). The inclusion of these goals was a helpful measure in validating the success of the geodatabase created for this thesis. Microsoft's guide also helped in creating the final SQL geodatabase for the Google API web-GIS map, discussed further in Chapter Three, by explaining the language behind database terminology. Microsoft's four final goals are to: (1) reduce redundant data; (2) join tables together; (3) identify the most accurate data; and (4) make sure the data is easy to query (Microsoft 2016). These four goals were the main determining factors in seeing if the geodatabase constructed in this thesis was effective in querying the drone use data contained within it.

2.6.3 Zeiler's Geodatabase Design Sequence

Zeiler (2010) offered a similar plan to the Microsoft guide to geodatabase design. In his book *Modeling Our World: The ESRI Guide to Geodatabase Concepts* he discusses the 11 steps necessary to create an effective geodatabase. Zeiler's guide was followed in the creation of the geodatabase used in this thesis. Zeiler advocated for identifying exactly what data needs to be in the geodatabase and then specifying the relationships and attributes needed for each layer to function properly. The only step that this thesis did not follow in the ascribed order from Zeiler's (2010) guide was to document the steps taken to create the geodatabase as the last step. Instead, this was done from the very onset of the geodatabase design. This allowed for a more detailed methods section to be created, and it may help users wishing to recreate this thesis by showing them in a detailed manner what worked and what did not work.

Chapter 3 Methods

This thesis provides a geodatabase and web-GIS map to help policymakers guide drone enthusiasts and the general public to areas of appropriate drone use within the state of Maryland. This chapter is split up into eleven subsections: (1) Intended user groups; (2) no-fly zone dataset creation; (3) geodatabase design; (4) Domain construction (5); the MSSQL construction (6); the Google API construction (7); the use overview of the HTML, JavaScript, and CSS programming languages (8); some additional background and supporting data (9); (10) web-GIS map creation; (11) and survey construction. A complete list of the steps taken to complete this chapter of the thesis is as follows.

The steps include determining the groups that would be using the geodatabase and web-GIS map; identifying the legislation and regulations pertaining to drone use from state and federal sources; converting all legislation and regulations into usable GIS data; acquiring background datasets; creating drone use datasets; designing the preliminary geodatabase; adding attributes and creating dataset links for the geodatabase; creating the domain; programming the website and web-GIS map; and uploading the data from the GIS map to the web-GIS map; construction and conduction of the survey.

3.1 Intended User Groups

This thesis aimed to benefit more than just GIS and drone experts; it allows anyone interested in drones or GIS technology, whether that be state government officials or the general public and drone enthusiasts, to locate appropriate areas of consumer drone use within the state of Maryland. The policymakers, the general public, and the drone enthusiasts can all use the products of this thesis; because of this, this thesis needed to be written so that all of the aforementioned groups would be able to obtain the information they might want from it. In this section, each of these three user groups will be identified to show what they could use the products of this thesis for and how this shaped the design of these products.

3.1.1 Policymakers

It is difficult to gauge the level of understanding of GIS technology that policymakers possess; some may have a great amount of knowledge on the subject; have no understanding of GIS technology; or have only a limited knowledge of drones and the laws surrounding them. Policymakers can use the web-GIS map to locate areas that drone use may be a cause for concern or to understand how and where drones are currently being used in their state or county. Due to this user group's potentially limited understanding of GIS, the geodatabase has been designed to be as simple as possible. The web-GIS map uses the same approach and allows ease of use to take priority over scientific sophistication. The geodatabase and web-GIS map are straightforward in terms of design, thereby allowing policymakers to use it to visualize current drone laws and limitations and interpret them more accurately.

3.1.2 The General Public

The general public includes everyone, from GIS and drone experts to people who have no knowledge of drones or GIS. The general public will be able to use the web-GIS map to see where drone use is permitted within their neighborhoods and to understand why and where no-fly zones exist. This thesis explains and visualizes drone legislation for anyone interested in understanding more about it.

3.1.3 Drone Enthusiasts

Drone enthusiasts will usually have more knowledge of drone laws than the general public and at least some knowledge of GIS technology. Drone enthusiasts will be able to use the web-GIS map to locate areas to fly their drones, as well as allow them to learn the steps that they would need to take to fly their drones in an area with drone flight restrictions. With this in mind, the geodatabase provides the web-GIS map with the data necessary to be both easy to use and informative for drone enthusiasts wanting to find useful tools for locating areas appropriate for drone use.

3.2 Interpreting Federal and State Legislation

This geodatabase and web-GIS map incorporates the regulations from the FAA, National Park Service (NPS), National Oceanic and Atmospheric Administration (NOAA), and the state of Maryland. Each of these government entities has regulations that limit drone usage in Maryland. In this section, the various laws and regulations and their sources are explained. The approach used to translate them into GIS data and facilitate the design of the drone use geodatabase, and web-GIS map is then described.

3.2.1 Federal Legislation

The FAA, which is in charge of governing the atmosphere of the U.S., is the main agency that regulates drone use. NOAA and the NPS, however, have also enacted drone use laws and regulations for their jurisdictions. The FAA has to approve the regulations promulgated by other agencies. This begins when the agency in question decides that another drone use regulation is needed to properly protect the intrinsic value of the According to the FAA publication, *State and*

Local Regulation of Unmanned Aircraft Systems (UAS) Fact Sheet, "the FAA has the exclusive right to govern the atmosphere of the U.S. and that only with its permission can other government organizations create drone usage regulations, with some exceptions for state regulations discussed in the next section" (FAA 2015b). Since the FAA has the authority to enact and evaluate drone use regulations, the vast majority of regulations turned into laws by Congress were originally created by the FAA.

The most frequent type of drone no-fly zones enacted by the FAA is those within five miles of airports or heliports (49 U.S.C. sec. 40101). The full set of federal laws and regulations passed by The United States Congress on behalf of the FAA, NPS, and NOAA is summarized below in Table 1. The FAA also has the right to extend any no-fly zone temporarily as it sees fit (U.S. Code of Federal Regulations 2013). These extended no-fly zones or temporary restricted no-fly zones are known by the acronym (TFR) or Temporary flight restrictions. The FAA's drone no-fly zone area around Washington, D.C. is particularly complicated. The entire city of Washington, D.C. is a no-fly zone (FAA 2016b) Although this zone is not technically inside Maryland, the state shares a border with Washington, D.C. Washington, D.C. also has one other no-fly zone, Ronald Reagan National Airport, which is actually in Virginia and not in Washington, D.C. but is used by Washington, D.C. as a drone no-fly zone indicator. The drone no-fly zone from Ronald Reagan National Airport can be anywhere from 15-30 miles in diameter, extending over 7-14 miles into Maryland (FAA 2016b).

Table 1 The federal drone use regulations, the corresponding laws, and the GIS skills needed to create them in the thesis.

Regulation	Source	Notes/References	GIS Skills Needed
Airport 5-mile Restricted No-fly Zone	US Congress and FAA Legislation 49 USC § 40101.336 (a)(5) (49 U.S.C. sec. 40101)	This was the first mandated drone use regulation. the full write up is contained in "The FAA Modernization and Reform Act of 2012"	Buffer from Centroid of Polygon
No Drone Flying Within National Park Boundaries	US Congress and National Park Service. 36 C.F.R.§ 2.17(a)(3). (U.S. Code of Federal Regulations 2003)	This regulation came about because of safety concerns and the potential for drones to damage the protected environments in National Parks.	Polygons of National Park Boundary
Major Stadiums & Their Extended No-fly Zones	US Congress and FAA Legislation 14 CFR § 99.7 (a) (U.S. Code of Federal Regulations 2013)	This includes both major league sports stadiums and college stadiums and has the potential to be used to setup temporary no-fly zones for any major gathering of people.	Points and Corresponding Buffers as Applicable
Heliports	US Congress and FAA Legislation 49 USC § 40101.336 (a)(5) (49 U.S.C. sec. 40101)	Heliports are considered airports in the eyes of the FAA in regards to drone use restrictions contained in "The FAA Modernization and Reform Act of 2012"	Polygon Centroid Points and Buffer
U.S. Military Bases	US Congress and FAA Legislation 49 USC § 40101.336 (a)(5) (49 U.S.C. sec. 40101)	As federal property US military bases already have restrictions on civilians entering them, this also applies to drones.	Polygon of Military Base Boundaries
Washington, D.C. 15 mile SFRA	FAA. SFRA (FAA 2016a).	This "temporary" flight restriction isn't set to be taken down until the year 9999 and begins at and includes all of the White House (AIRMAP 2016).	Point at Ronald Reagan Airport Where the Buffer Originates
Temporary/ Extended No-fly Zones	US Congress and FAA. 14 CFR § 91.137 (91)(b) (U.S. Code of Federal Regulations 2013)	These no-fly zones may expire at a certain time like the extended no-fly zone around the Super bowl or technically not expire as in the case of Washington, D.C.	Extended Buffer from Points with Temporary/Extended No-fly Zones
Department of Commerce / National Oceanic Atmospheric Administration. Marine Reserves	US Congress and Department of Commerce. 16 USC § 1431 (16 U.S.C. sec 1431).	The boundaries and the area contained inside them constitute the drone no-fly zones for this regulation.	Polygon Around Boundary of All Marine Reserves
Privacy Rights / Private Property No-fly Zones	FAA. FAA-2015-0150 (FAA 2015b)	This legislation stipulates that drone regulations can be created with FAA consent by state governments, which has only recently begun to occur.	Point and Polygon Shapefile Creation

The FAA also has no-fly zones around military bases and sensitive sites. Camp David, the president's "weekend house" in Thurmont, Maryland, is one such example (FAA 2012). The main FAA drone use laws are laid out in the "FAA Modernization and Reform Act of 2012" and the FAA's "Interpretation of the Special Rule for Model Aircraft" (49 U.S.C. sec. 40101). The FAA regulates other federal agencies' atmospheric regulations and drone policies.

NOAA is responsible for the regulation of the territorial water ways of the U.S. With permission from the FAA, NOAA enacts drone no-fly zones over marine reserves and critical water habitats (16 U.S.C. sec. 1431). The land equivalent of NOAA is the NPS, which enacted its own legislation preventing drone use within the borders of its parks (U.S. Code of Federal Regulations 2003). These are the federal laws related to limiting drone use.

3.2.2 State Legislation

Due to the limitations put in place by the FAA in 2015, state governments can only mandate drone regulations pertaining to several state regulated activities: Hunting, personal privacy, state-regulated lands, and use by law enforcement (FAA 2015b). Maryland has only enacted one major drone use law, in which they limited the use of drones by law enforcement personnel without a warrant. The state will most likely be responsible for regulating private property drone permissions in the near future, though the state's ruling on this is not slated for release until 2018. The only other drone use law in place in Maryland is that its state parks have banned drones in Montgomery and Prince Georges Counties (MNCPPC 2001). Both of these laws and how they are translated into GIS data inside the map are summarized in Table 2 below.

Table 2 Drone use laws created by the state of Maryland and the GIS tasks that were executed to use them.

Regulation	Source	Notes/References	GIS Skills Needed	Representation
Privacy Rights / Private Property No-fly Zones	FAA. FAA-2015-0150 (FAAa 2015	Currently, there is no official Legislation for private property no-fly zones except in the case of sports stadiums.	Point and Polygon Shapefile Creation	Purple Polygons/ Points
State Parks No Taking off/ Launching Powered Airplane Models/Rockets	MD DNR Regulations 2001 Section 15 Chapter 5	This currently only applies to Montgomery and Prince Georges Counties	Polygon Shapefile Creation	White Polygons

3.2.3 Legislation Translated into GIS Data

To properly translate these laws into GIS data, different GIS techniques were used, as shown above in Tables 1 and 2. Each law was studied to see how it would affect the map; whether the law talked about a building such as stadiums or a large area like the boundaries of national parks; and then it was translated into GIS data accordingly. Points were used to show the locations of stadiums, airport polygon mid-points, and heliports. Polygons were used for marine reserves, national and state park boundaries, and military bases. For no-fly zones that extended past the boundaries of points or polygons, the spatial analyst buffer tool was used to create buffers of corresponding distances from each classification of point and polygon. Finally, different colors were used to classify the legislations, and buffers were classified as 50% transparent to allow users to see what areas these covered. This is how the legislation was converted from written word to web-GIS map features.

3.3 No-Fly Zone Dataset Creation

Dataset creation is only possible when data is available. All geospatial data was obtained from the state of Maryland's iMAP geoportal, Esri, and Google Inc. or created from scratch based on legislation. The datasets used in the creation of the geodatabase and web-GIS map are shown in Table 3. In this section, the datasets that were used to create the geodatabase and web-map for Maryland are explained; a more detailed analysis of how the drone no-fly zone datasets were created is offered.

Table 3 The required background datasets and their sources needed to complete this thesis.

Required Data	Data Description	GIS Technique	Source	Required Skills	Data Cost	Data Quality
MD State Boundary	Vector Line	Boundary Layer	MD iMAP	ArcGIS 10.1, Import Data, Convert Projection	Free	Created in 2013
MD County Boundaries	Vector Polygon	Boundary Layer	MD iMAP	ArcGIS 10.1, Import Data, Convert Projection	Free	Created in 2013
MD Satellite Imagery	Imagery	Base Map	MD iMAP	ArcGIS 10.1, Import Data, Convert Projection	Free	Created in 2013, 6inch Accuracy
MD Water Bodies	Vector Line	Boundary Layer	MD iMAP	ArcGIS 10.1, Import Data, Convert Projection	Free	Created in 2013
Website Domain	Website Platform	Website Platform	Dreamhost.com	Website Creation, Basic JavaScript, and HTML Programming	Under $20.00	Thesis Panel and General User Review

3.3.1 Study Area Background Data

The study area for this thesis, shown in Figure 1, borders Washington, D.C. and contains many vital federal government facilities. Because of this, allowing drone legislation to be visualized is important to allow its residents to better understand it. The background dataset that was chosen to complete the web-GIS map was a 2016 satellite six-inch accuracy imagery basemap obtained from Esri. Esri provides this map for free to users provided that they include the source citation in their work. Polygon boundaries, concerning both the entire state and all of the counties, were acquired from iMAP.

The next dataset allowed the creation of the no-fly zones by providing features and attributes that could be used to represent the location of no-fly zones on the map. This dataset is from Maryland's iMAP's 2013 index of property boundary polygon parcels. All the datasets, excluding Esri's basemap, come from the state of Maryland's iMAP geoportal and were necessary in creating the drone use geodatabase and web-GIS map of Maryland.

3.3.2 No-Fly Zone Data

The no-fly zone data for this thesis had to be created from scratch and required several steps to complete. The data, its sources, and its costs are listed in Table 4. The methods used to locate the data, check its accuracy, and create the GIS data are described next. The first thing that had to be established was what data was required to make an accurate drone use map for the state of Maryland.

Table 4 The manually created drone use datasets needed to complete this thesis.

Required Data	Data Description	GIS Technique	Source	Required Tasks	Data Cost	Data Quality
Major Stadiums	Vector Point	Layer/Buffer	Google Maps	Editor Toolbar, Convert Feature to Shapefile	Free	Will be created with Gps Coordinates
Airports	Vector Point	Layer/Buffer	Google Maps	Editor Toolbar, Convert Feature to Shapefile	Free	Will be created with Gps Coordinates
National Parks	Vector Polygon	Layer/ Buffer	National Park Service	Editor Toolbar, Convert Feature to Shapefile	Free	Created in 2016
Military Bases/ Sensitive Sites	Vector Polygon	Layer	Google Maps	Editor Toolbar, Convert Feature to Shapefile	Free	Created in 2016
No-fly Zones	Vector Polygon	Buffer/Layer	FAA Legislation	Spatial Analyst, Buffer, Convert Feature to Shapefile	Free	Compared Against Current FAA Maps

Data that was deemed necessary to collect came from legislation from the FAA, NPS, NOAA, and the state of Maryland. These sources indicated what sites and locations would need to be included in the drone use geodatabase and web-GIS map. To explain how these data types were created, the example of Whalen Field Airport in Kent County, Maryland is used. The steps taken to specify the location of this point is the same for dataset type and feature described in this thesis. A full list of these dataset types and their sources was provided above in Table 5. According to the FAA, airports have a five-mile restricted drone no-fly zone around them (FAA 2012). Now that the need to create a point to represent this location in the geodatabase and web-GIS map has been established, the work creating it can be described.

The most pressing concern was to make sure that the location of these features was as accurate as possible. Its accuracy was verified by comparing each point/polygon to other professional sources. This airport was located by typing a query into Google Maps for airports in Kent County, MD and seeing a label for it appear, as shown in Figure 7. To make sure all airports were reported for each county, a public records website for Maryland pertaining to airports was checked (www.tollfreeairline.com). A final investigation into the airports was conducted at the FAA's website of active airports to make sure all listed airports were still active. It was then checked to see if it was still an active airport by seeing if it was included in the FAA's B4UFLY cellular application, shown in Figure 8. The B4UFLY cellular application was also used to check for airports that did not show up in Google Maps queries. Once Whalen Airport had been verified as an active airport, a point was created to indicate its location on the map.

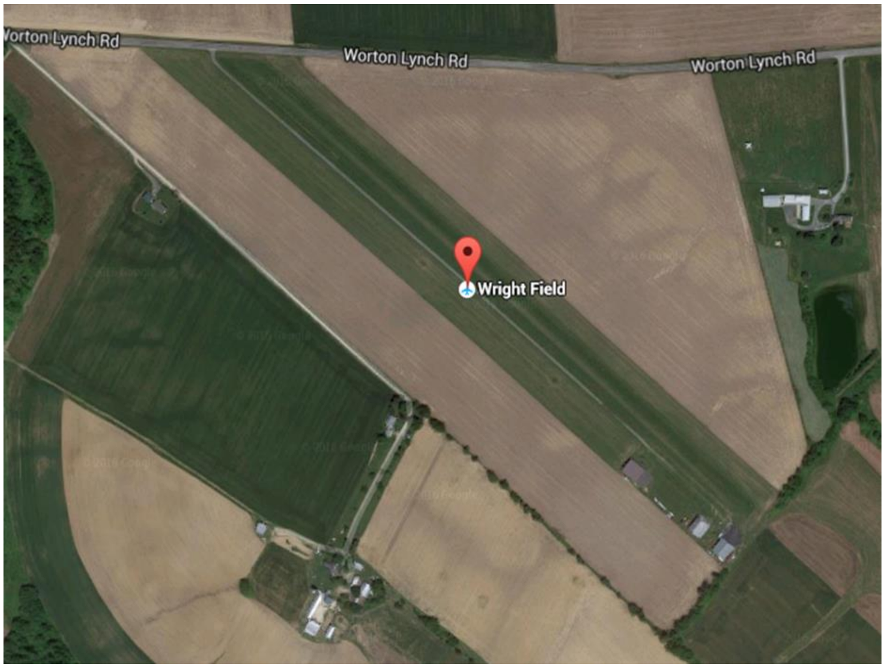

Figure 7 Wright Field Airport as it appears in Google Maps (https://www.google.com/maps/place/Wright+Field/).

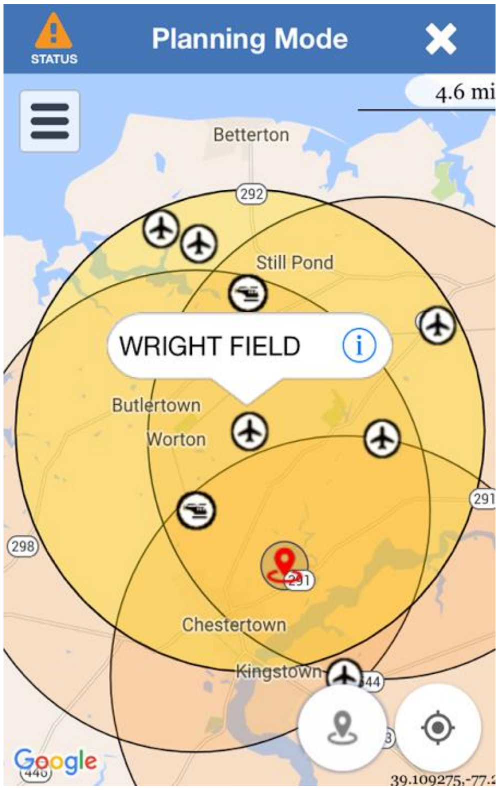

Figure 8 Wright Field Airport as it appears in the FAA's B4UFLY cellular application (FAA 2016a).

On the surface, this task would seem like an easy undertaking. The reality, however, was quite the opposite. Defining the true borders of the airport was difficult. There were no written guidelines on where a buffer should begin, whether it should rely on the parcel boundary in which the airport is contained, the center point of the parcel, or on some other protocol. No rule on how this is determined is clearly defined by the FAA. After contemplating several options, choosing to place a polygon centroid point in the middle of the parcel polygon for the airport was determined to be the best choice. An estimate was taken of the centroid for the x and y coordinates for every polygon in each county. The data was then exported and visualized as centroid points on the map. There may be some errors with this approach, but the lack of clear guidance on this meant that a centroid point seemed to offer the best compromise for creating the point data for the drone use GIS map.

Simple snapping was then used to put a point on top of the centroid point where the airport was located. After this point was created for Wright Field Airport, it was transformed into a shapefile layer in edit mode. Attributes were then added to the point for Wright Field Airport. The spatial analyst toolbox was used to create a five-mile buffer from this point, as illustrated in Figure 9. The attribute data was then merged with the buffer. This process was repeated for every airport and heliport in Kent County, and eventually for all other counties in Maryland. The steps to create a point and a polygon are essentially the same, with the only difference being that the iMAP parcel boundaries were used instead of the centroid point method. The next section explores the details on how the geodatabase was designed.

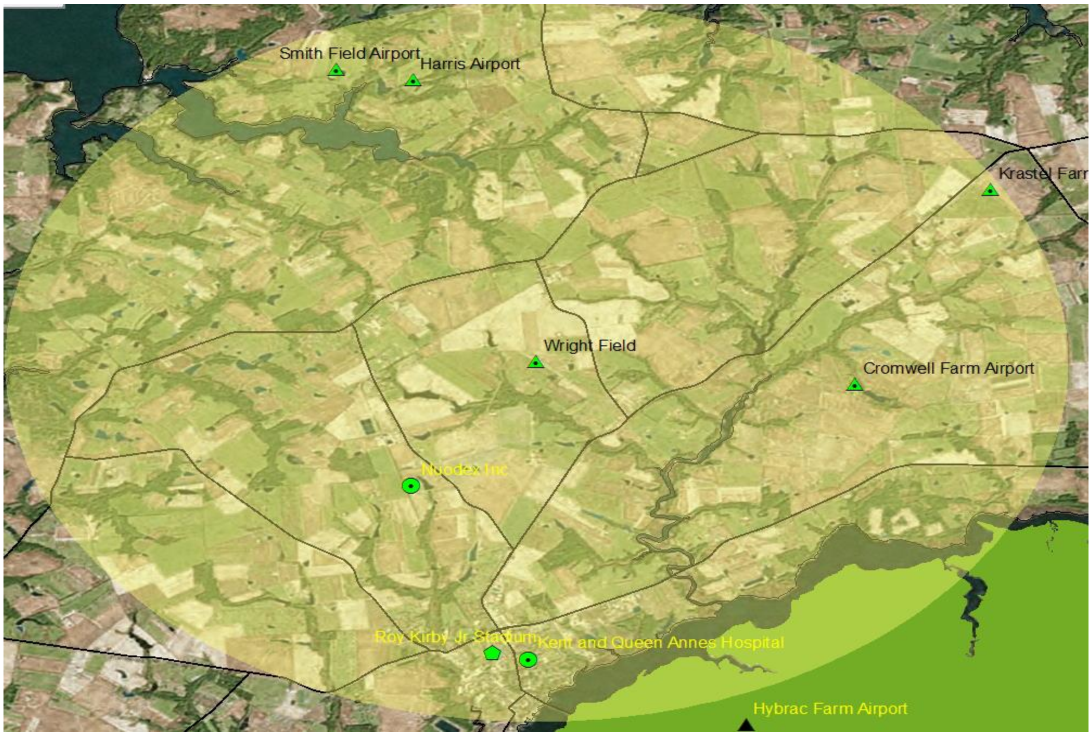

Figure 9 Wright Field Airport in ArcGIS prior to transferring it to the Web platform.

3.4 Geodatabase Design

The geodatabase designed for this thesis was born out of the advice from three main sources: Microsoft's (2016) guide to database designs*;* Zeiler's (2010) guide to geodatabase design, and *A Unified Geodatabase Design for Sinkhole Inventories in the United States* (Khan 2016). The initial design of the geodatabase for this thesis was unnecessarily complex. Over time, eliminating superfluous data simplified the geodatabase. The steps taken to create the geodatabase included assigning attributes, creating links to datasets primary and foreign keys, and finalizing the geodatabase so it could be used to formulate queries.

3.4.1 Adding Attributes

Attributes were added to each dataset to allow proper linkage of the datasets so that data could be easily accessed. In this section, the attribute tables for the state of Maryland, points, polygons and parcels are summarized. Along with these attributes, the way that these datasets fit together will be explained. In the tables, “PK” refers to a primary key, which is a unique identifier for each dataset that is not repeated. “FK” refers to a foreign key and is the linkable trait that allows datasets to be connected. Tables 5-8 below also share each attribute’s name, classification, and the source of that data.

Table 5 Attribute data for the State of Maryland.

Key	**Attribute Name**	**Attribute Classification**	**Source**
PK	State_Name	Character	iMAP
FK	CountyName	Character	iMAP
	Area_SQMI	Float	iMAP
	Population	Integer	iMAP

Table 6 The attributes for point data such as airports, heliports, stadiums, and sensitive sites.

Key	**Attribute Title**	**Attribute Classification**	**Source**
PK	Point_Id	Integer	User Created
FK	CountyName	Character	iMAP
	Owner_Name	Character	iMAP
	Website	Float	Google Inc.
	Contact_Number	Integer	Google Inc.
	Latitude	Float	Google Inc.
	Longitude	Float	Google Inc.

Table 7 Attribute data for polygon datasets such s as national park boundaries.

Key	**Attribute Title**	**Attribute Classification**	**Source**
PK	Polygon_Id	Integer	User Created
FK	CountyName	Character	iMAP
	Owner_Name	Character	iMAP
	Website	Float	Google Inc.
	Contact_Number	Integer	Google Inc.
	Latitude	Float	Google Inc.
	Longitude	Float	Google Inc.

Table 8 The attribute data for the parcel boundary dataset for the State of Maryland.

Key	**Attribute Title**	**Attribute Classification**	**Source**
PK	Parcel_Id	Integer	iMAP
FK	County_Name	Character	iMAP
	Owner_Name	Character	iMAP
	Zoning	Float	iMAP

3.5 Domain Construction

In order to properly display the data from the geodatabase and GIS map, a website was created to allow broader access and use of the data from both sources. The website domain chosen to host the final drone use map for the state of Maryland. (Dreamhost.com) was not free, but the site did allow the purchase of domains with unlimited subpages for an annual fee. The website that houses the final web-GIS map created for this thesis is located at: http://www.cyberclockgames.com/Brendan/.

3.6 MSSQL Database Construction

After the website domain was acquired, data was then exported from Esri's ArcMap into useable csv data that could be imported into the web database. For this website, Microsoft's Sequel Server (MSSQL) was used as the database management tool. Each dataset from ArcMap was downloaded individually and then imported into MSSQL. The CSS programming language explained below allowed a link to be created from the database to the website so the data could be queried more efficiently. An example of one of the database tables for airports from MSSQL is shown in Figure 10 below. The entire MSSQL database is contained in Appendix A.

Name	Type	Owner	Tower_Present	Website	Use	Contact_Number	Area	Lat	Lng	County
Schlosser Airport	Farm_Airport	Schlosser Family	No	No	Private	4107556608		39.3630905	-75.8131638	Kent
Massey Aerodrome	Farm_Airport	Massey Family	No	masseyaero.org	Public	4109285376		39.3016815	-75.7988358	Kent
D'Angelo Farm Airport	Farm_Airport	Unknown	No	No	Private	4107556864		39.3404732	-75.7723236	Kent
Smith Field Airport	Farm_Airport	Unknown	No	No	Private	9082362880		39.3361244	-76.0981979	Kent
Harris Airport	Farm_Airport	Unknown	No	No	Private	4103485184		39.3341522	-76.0847626	Kent
Krastel Farm Airport	Farm_Airport	Krastel Family	No	No	Private	4103485184		39.3119659	-75.9834442	Kent
Cromwell Farm Airport	Farm_Airport	Cromwell Family	No	No	Private	4107605760		39.272892	-76.0072327	Kent
Wright Field	Farm_Airport	Wright Family	No	No	Private	4107784192		39.2773323	-76.0631943	Kent
Pond View Airport	Farm_Airport	Unknown	No	No	Private	0		39.2684898	-76.1875305	Kent
Breezecroft Airport	Farm Airport	Unknown	No	No	Private	4107781120		39.2440605	-76.1997452	Kent
Breezecroft Seaplane Airport	Seaplane_Dock	Unknown	No	No	Private	4107781120		39.2504654	-76.204895	Kent
Garrett County Airpark	Public_Airport	County_Gov	No		Public	0		39.5814209	-79.3370819	Garrett
Ward's Airport	Farm_Airport		No		Private	0		39.4309273	-79.454216	Garrett
Garrett Regional Hospital Heliport	Hospital_Helo		No		Private	0		39.4133797	-79.401268	Garrett
Herrington Field Airport	Farm_Airport		No		Private	0		39.4705963	-79.4256592	Garrett
Mexico Farm Airport	Public Airport		No		Public	0		39.6062126	-78.7591324	Allegany
Hagerstown Regional Airport	Public Airport		Yes	flyhagerstown.com	Public	2403132672		39.7092743	-77.729538	Washington
Laura's Landing	Farm_Airport		No		Private	0		39.5870552	-77.6460342	Washington
Cacotin Airport	Farm_Airport		No		Private	0		39.6449013	-77.3668671	Frederick
Frederick Municipal Airport	Public	County_Gov	Yes	cityoffrederick.com	Public	3016002304		39.4163399	-77.3739014	Frederick
Ijamsville Airport	Farm_Airport		No		Private	0		39.3608971	-77.3418655	Frederick
Burhans Memorial	Farm_Airport		No		Private	0		39.3475685	-77.3367386	Frederick
Good Neighbor Farm Airport	Farm_Airport		No		Private	3018315520		39.4741936	-77.1932907	Frederick
Harrison Farm Airport-8MD5	Farm_Airport		No		Private	3018290176		39.5007019	-77.2240067	Frederick
Harp Airport	Farm_Alirport		No		Private	3012932864		39.5972481	-77.5454178	Frederick
Ridgely Airpark	Public				Public	0		38.9695511	-75.8673325	Caroline
Carmean Airport	Farm_Airport		No		Private	4106342912		38.9317589	-75.8839722	Caroline
Gary Field	Farm_Airport		No		Private	3016342528		38.898571	-75.9099655	Caroline
Spiering Airport	Farm_Airport		No		Private	4104828160		38.9798279	-75.7769241	Caroline
Magennis Farm Airport 7MD1	Farm_Airport		No		Private	4107549440		38.7062531	-75.849762	Caroline
Slater Field 00MD	Farm_Airport		No		Private	4107548672		38.756916	-75.7521286	Caroline
Greer Airport MD20	Farm_Airport		No		Private	0		39.6897049	-77.247612	Frederick
Flying Acres Airport	Farm_Airport		No		Private	4104383488		39.1835861	-75.9104309	Queen Annes
Roseland Nurseries Airport	Farm_Airport		No	roselandnurseries.com	Private	4107556608		39.1906357	-75.8778229	Queen Annes
Taylor Field Airport	Farm_Airport		No		Private	4104383232		39.1834259	-75.790741	Queen Annes
Whalen Field Airport	Farm_Airport		No		Private	4107784192		39.1682625	-75.8394165	Queen Annes
Ashland Landing Farm Airport	Farm_Airport		No		Private	4107886592		39.1154671	-76.0897598	Queen Annes
Kennersley Airport	Farm_Airport		No		Private	4105566464		39.1450272	-76.0401993	Queen Annes
Saxon Farms Airport	Farm_Airport		No		Private	0		39.1529884	-76.0183182	Queen Annes

Figure 10 Part of the airports table from the MSSQL database.

3.6.1 Database Changes

The database constructed in MSSQL was different from the one constructed in ArcMap in a couple of ways and for different reasons. The first major difference is that the parcel dataset was omitted. This was because each county in Maryland starts their parcel identification at one and then proceeds on from there. This made it possible for two parcels in separate counties to have the same parcel ID. Since the parcel ID in that dataset was the primary key and had to be unique this dataset had to be removed. The other difference was that point data (airports, heliports, and other points) were separated into separate datasets to allow their data to be more easily manipulated in MSSQL.

3.7 Google Maps API

The web-GIS data needed to be displayed in an easily accessible manner so that various groups could use it. There were many options available to display GIS data on the web: MapBOX, Airmap, Bing Maps and Google Maps, to name a few. For this thesis, the Google Maps API was chosen not only because it was available for free, but also because it offered a wealth of free tutorials and step-by-step instructions on its functions and use. A Google Maps API allows website designers to download a key to embed an editable copy of Google Maps into their website, as shown in Figure 11. This map can be utilized with a satellite view, which can display optional labeled or unlabeled aerial imagery of Maryland; or with a map view, which provides an option to display topography. The web-GIS map as it is displayed to site visitors is shown in Figure 12.

Figure 11 The Google Maps API background for this thesis' web-GIS.

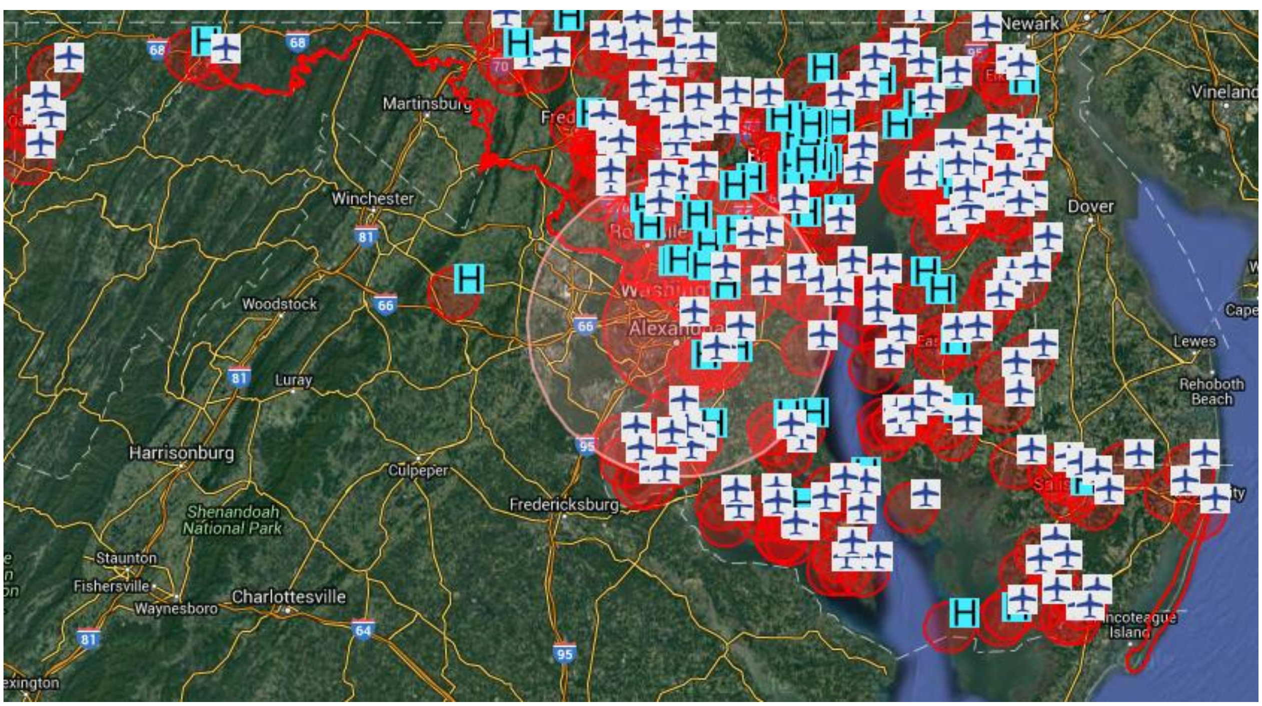

Figure 12 How the web-GIS map looks when site visitors open the website.

Although the lens through which the map is viewed is up to the website visitor, the view that allows the most information to be gathered from this map is the satellite view with the labels option turned on. These settings are used to present the map when visitors first view it. The Google Maps API background map that the drone use data for this thesis sits on is the same map because most users will have some familiarity with navigating within in it.

3.8 Programming Languages

The three programming languages used to construct the web-GIS portion of this thesis were HTML, JavaScript, and CSS. Each one of these programming languages was used for specific aspects of the final web-GIS map. Google provides step-by-step instructions on how to program within their Google Maps API, where the majority of this programming was done. The complete programming code used to construct the website and program the web-GIS map is referenced in Appendix B.

3.8.1 HTML

HTML is a programming language web designers use to construct websites. Primarily it is used to construct the layout and placement of items within the website. For this thesis, HTML was used to construct the headers and footers of the website; where to find additional information on drone use legislation and regulation; the background history of drone use laws; and how the information on the geodatabase is stored.

3.8.2 JavaScript

JavaScript is another programming language that is used to create actions and functions within websites and applications. For this thesis, JavaScript was used to create the interactions inside the Google API map. These interactions let the website visitors parse through the data by clicking and moving around the map and its supporting data. Some of the JavaScript interactions include clicking on points and having information about them appear; clicking on links and being taken to additional websites; and having buffers appear when a user's mouse hovers over a point.

3.8.3 CSS

CSS is the third major programming language that was used to construct the web-GIS portion of this thesis. CSS was used to make the website that the Google Maps API web-GIS map sits on look professional and appealing to visitors. Having a website that looks professional is important because it sets the tone for the information being presented to the website's visitors. Examples of CSS code used in the construction of the web-GIS map website can be found at: http://www.cyberclockgames.com/Brendan/.

3.8.4 Interactions

The website and the Google Maps API web-GIS map constructed to show areas of appropriate and inappropriate drone use in Maryland have several interactive features that were created using the various programming languages discussed above. Each point or polygon has a pop-up bubble that appears when it is selected. The pop-up bubble displays the type, title, and contact information of the no-fly zone shown in Figure 13. The header provides a menu that allows users to access background information on drone use, federal and state legislation and access to the drone use survey shown in Figure 14. Different types of no-fly zones have been programmed to have different labels, as detailed in the legend in the footer of the website shown in Figure 15. The map contains a scale bar in the lower right corner. This feature allows users to switch between imperial and metric measurements of distance, shown in Figure 16. In Figure 17, the directional North arrow is displayed, allowing map visitors to orient themselves to geographic North. Finally, users can pan and zoom in and out of the web-GIS to navigate to different areas of the map to see all of the 200+ no-fly zones contained in the map.

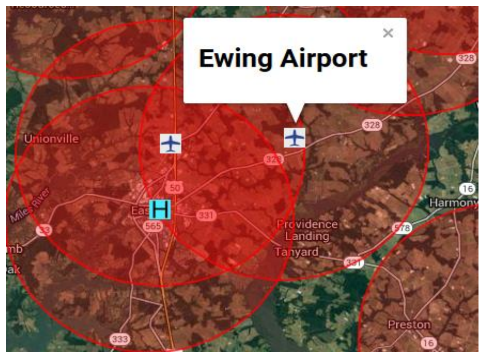

Figure 13 A clickable pop up bubble containing information about a no-fly zone location.

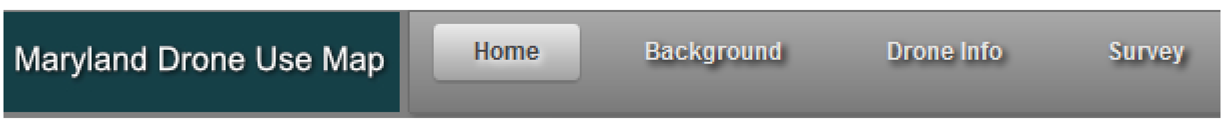

Figure 14 The menu bar located in the header created with code from the CSS Portal (CSS Portal 2016).

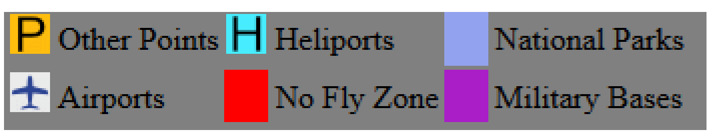

Figure 15 The legend as displayed in the footer of the website, below the web-GIS map.

Figure 16 The scale bar as displayed in the footer of the website, below the web-GIS map.

Figure 17 The North arrow as displayed in the web-GIS map.

3.9 Additional Website Data

Besides the web-GIS map of areas of appropriate and inappropriate drone use in the state of Maryland, additional information is contained in the headers and footers of this website. The header has separate pages that contain links to data on drone use laws and regulations in the U.S. as well as the state of Maryland. There is also a link to a page on the background data and motivation to build this website. A sample of some of the links and their explanations is provided in Figure 18.

https://www.faa.gov/uas/registration/

(this website defines what a recreational or consumer drone and explains how to properly register that drone)

http://www.faa.gov/uas/regulations_policies/media/UAS_Fact_Sheet_Final.pdf

(The FAA's explanation of what laws States can put in place pending approval from the FAA)

https://www.faa.gov/uas/regulations_policies/media/Sports_TFR-UAS_Handout.pdf

(this website explains what temporary flight restrictions are and explains how they are used around stadiums)

https://www.faa.gov/uas/media/Sec_331_336_UAS.pdf

(An excerpt from the FAA's Modernization and Reform Act of 2012 on acceptable drone use)

Figure 18 Some of the links from the web-GIS website on drone use regulation.

3.10 Web-Map Creation

Once the geodatabase was established, work began creating the final web-GIS map and uploading the data contained within it to the web-GIS platform, Dreamhost.com. The final web-GIS map was created in ArcGIS Pro 10.3.1. One of the beneficial features of using ArcGIS is that users have access to file conversion and many other software functions and tools. This access allows users to save datasets in different formats and supports data transfers to other platforms. The final GIS map contains all of the datasets that were used to create the web-GIS map. The attributes for these datasets can be seen in Tables 6-9 above. This section will present an overview of how the data was taken from the final GIS map and converted into usable data for the web-GIS map.

3.10.1 Data Conversion / Upload

Once the web-GIS map was compiled in ArcGIS 10.3.1, the datasets contained within that map were downloaded as a text (txt) file type. The datasets were then uploaded to the web-GIS map database builder, Microsoft's Sequel Server (MSSQLS). This was accomplished by exporting and downloading each dataset as a txt file, and then uploading these txt files into MSSQLS and linking them with the PKs and FKs, as outlined in Tables 6-9 above. After the MSSQLS database had been completed, the database was linked to the web-GIS map on the Dreamhost.com website through the programming language called personal home page (PHP).

3.10.2 Web-Map Creation

After the geodatabase had been developed, the final map could be created. Once the database had been linked, its data was uploaded to the Dreamhost.com website, a web platform that allows users to create their own website domains. The map portion of this website sits on a Google Maps application programming interface (API) map. This allows website visitors to use Google Maps to easily navigate and view the final geodatabase of airports, heliports, stadiums, national parks, military bases, and other drone no-fly zones within the state of Maryland. The only step required to use the Google API was the downloading of a key from http://www.google.com, which allows the creation of an embedded, editable Google map on the Dreamhost.com website. Adding the datasets from MSSQLS to the Google API was possible because of the latitude and longitude coordinates included with each point and polygon in each dataset. Further programming to download the data from MSSQLS was accomplished with AJAX/ JavaScript and will be explained in Chapter Four. Other features of the web-GIS included HTML, CSS, and JavaScript programming language data.

The Dreamhost.com website contained a header and a footer, both of which contained links to relevant legislation on drone use and other factual drone information, including contact information for federal and state agencies responsible for enforcing drone use laws. This portion of the website was programmed in AJAX JavaScript code. Additional information was added to the header and footer, including a history of drone use in the U.S. and a legend for the map. To evaluate the knowledge gained by visitors to the web-GIS map, a survey was embedded into the web-GIS map website for users to fill out. The results of constructing the geodatabase and web-GIS map are examined in the next two chapters.

3.11 Survey Construction

The survey constructed to determine the effectiveness of the Web-GIS map created for this thesis to visualize drone use in the state of Maryland was inspired by the ones created by

Daniel Gerard and Christopher Weidemann in their theses. (Gerard 2014, Weidemann 2013). The survey was created on http://Surveymonkey.com and consists of ten questions ranging from demographic information on participants to gauging what worked best in the map and website and areas to suggest improvements in both. The survey was posted publically on Facebook to collect a wide variety of respondents. An example of one of the questions is shown in Figure 19, and a copy of the questions is provided in Appendix C. The results of the survey are analyzed in the next two chapters.

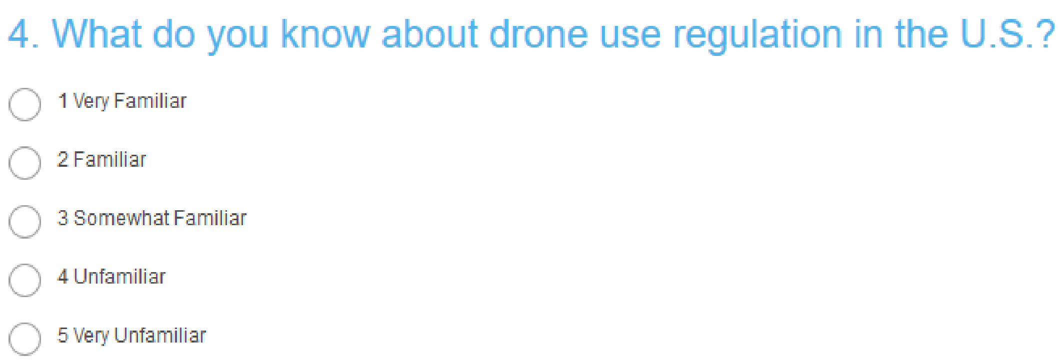

Figure 19 Question four of 10 from the optional survey attached to the web-GIS website to evaluate the success of the site in informing visitors about drone use in the state of Maryland.

Chapter 4 Results

The construction of a geodatabase to display drone use areas in Maryland could not be completed until it could be visualized, and thus understood by a broader audience. This was accomplished in the second half of this thesis. The final geodatabase design is presented, the final web map is analyzed, and the website evaluation survey is analyzed in this Chapter.

4.1 Database Final Design

In the previous chapter, the attribute data was explained. Now that the linkages and attributes for the datasets in the geodatabase have been explained, the final geodatabase design can be presented. The final geodatabase design is shown below in Figure 20.

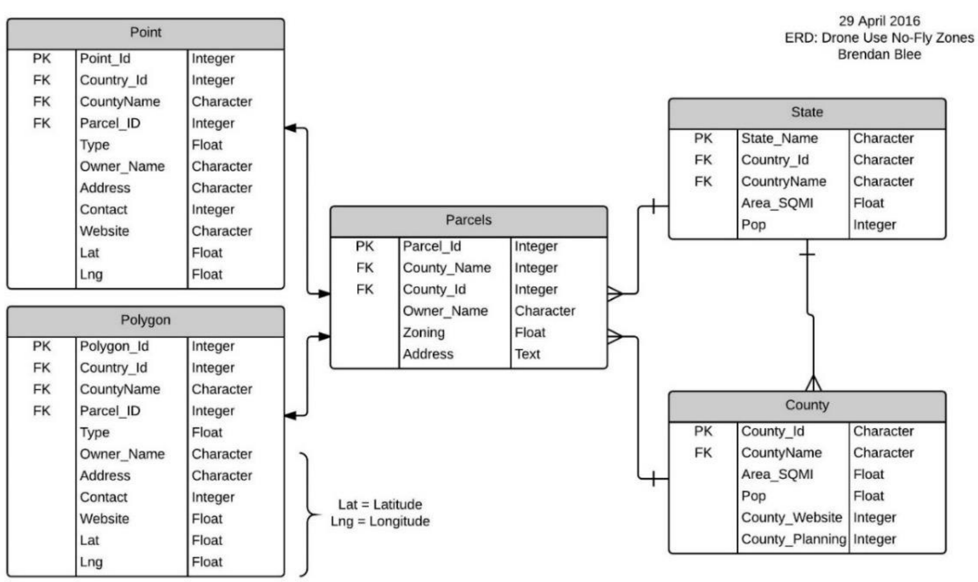

Figure 20 Final design of the geodatabase integrated into the web-GIS map for drone use.

4.2 Final Web-GIS Map

The final web-GIS map displaying the areas appropriate and inappropriate drone use in the state of Maryland is shown below in Figure 21. The web-GIS map shows 152 airports, 62 heliports, four sensitive sites, 31 military bases, and 9 National Parks. All of these are no-fly zones and are detailed further in the background tab and legend on the Maryland Drone Use Map website. In the Drone Info tab links to drone regulations, airport, National Park, and the FAA’s website for TFRs are contained.

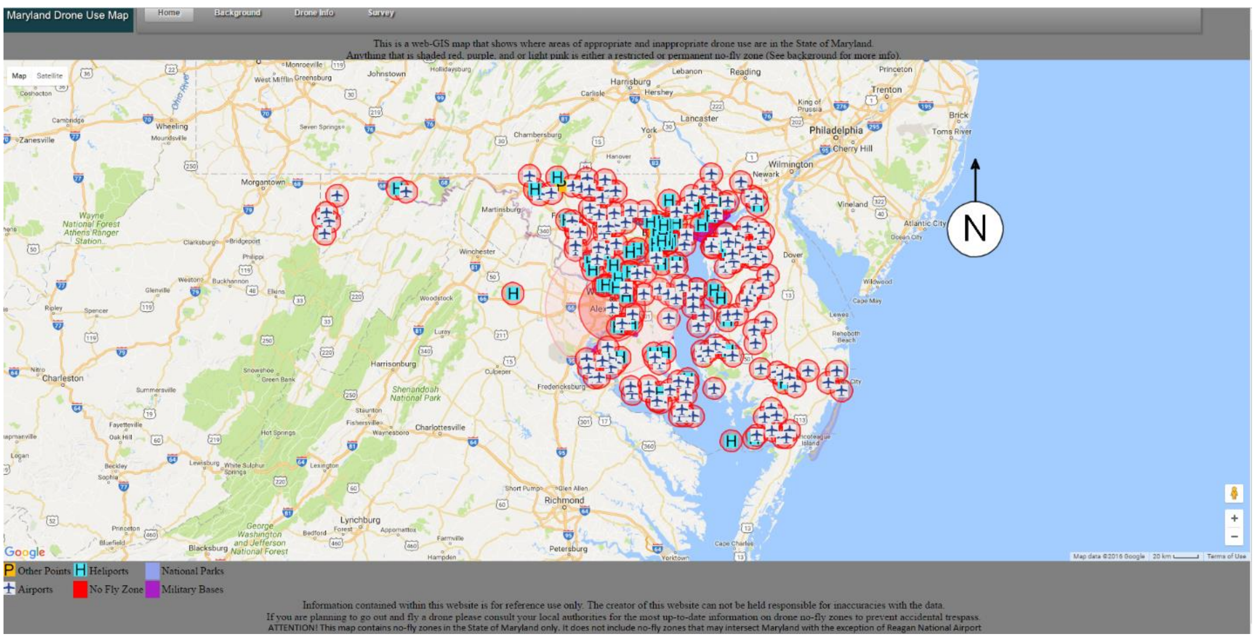

Figure 21 The final web-GIS map of areas of inappropriate and appropriate drone use in the state of Maryland.

4.3 Web-GIS Evaluation Survey

To evaluate if the web-GIS was successful at informing people about where it is appropriate and inappropriate to use drones in Maryland, a survey called Drone Use Map Questionnaire was created with SurveyMonkey.com and embedded into the website on a separate page. This optional survey will be used to gauge the background of site visitors and how much knowledge they had before and after visiting the site. It includes multiple choice, short answer, and scale-based questions to evaluate the site and suggest any improvements that should be made to enhance the website in the future. The significance of the results of this survey is discussed in more detail in Chapter 5.

4.3.1 Survey Results and Analysis

Each individual question is discussed and analyzed in Figures 20-27 and Table 9. The survey responses have been positive, with 17 total respondents and 70% of people indicating that the web-GIS map was able to effectively convey to them the drone use no-fly zones for the state of Maryland.

Questions 1 and 2 (Figures 22 and 23) summarize the demographics of the survey respondents and that 53% of the respondents were between the ages of 25-34 and that they spanned a diverse set of occupations. Information about the demographics of website visitors is important to minimize bias in survey results. The results for Question 3 shown in Figure 24 indicate the background knowledge survey respondents have on recreational drones. With 88% of respondents having at least some basic knowledge of what recreational drones are, it is safe to say the majority of website visitors are going to this website to learn more about drone use so they can use drones themselves. The results for Question 4, also shown in Figure 25, show that 52% of the respondents were unfamiliar with drone use regulation before visiting the website.

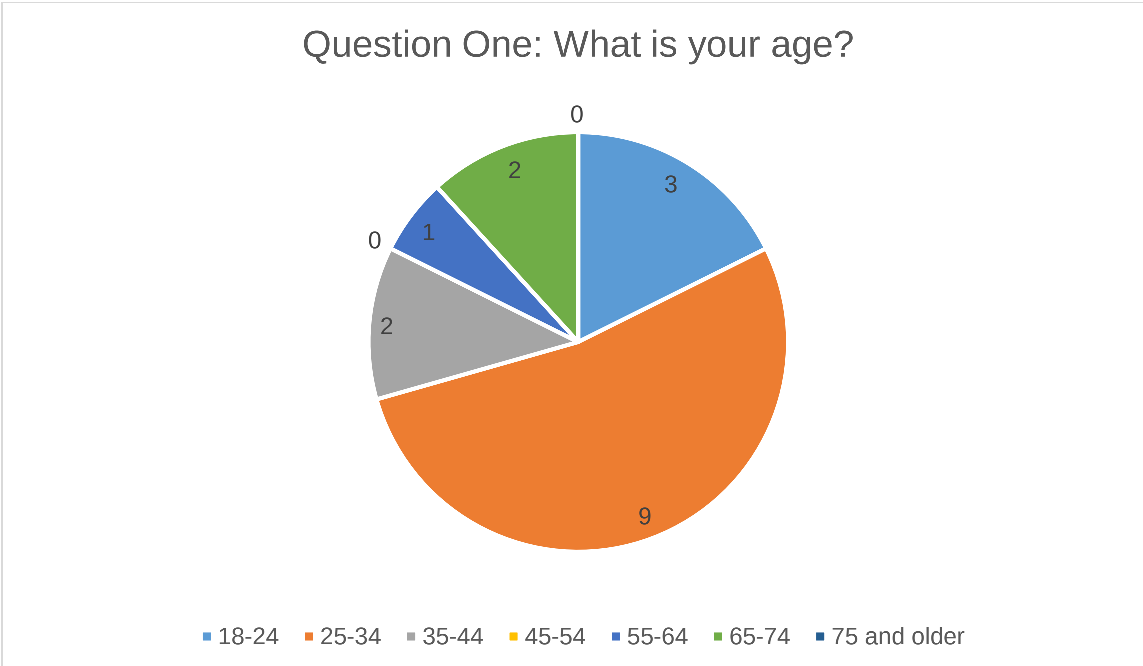

Figure 22 Results of question one of the survey to establish respondents' ages.

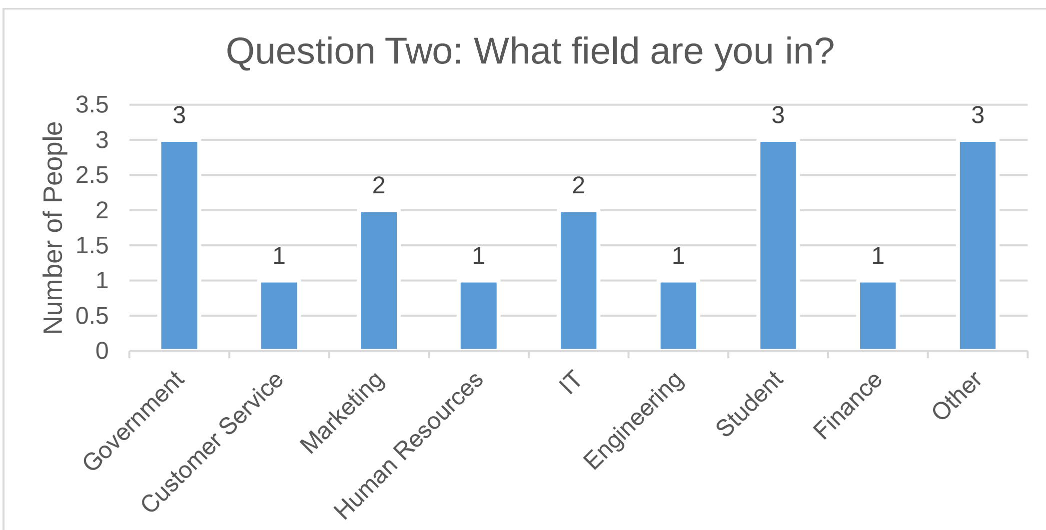

Figure 23 Results of question two of the survey to help establish respondent's backgrounds.

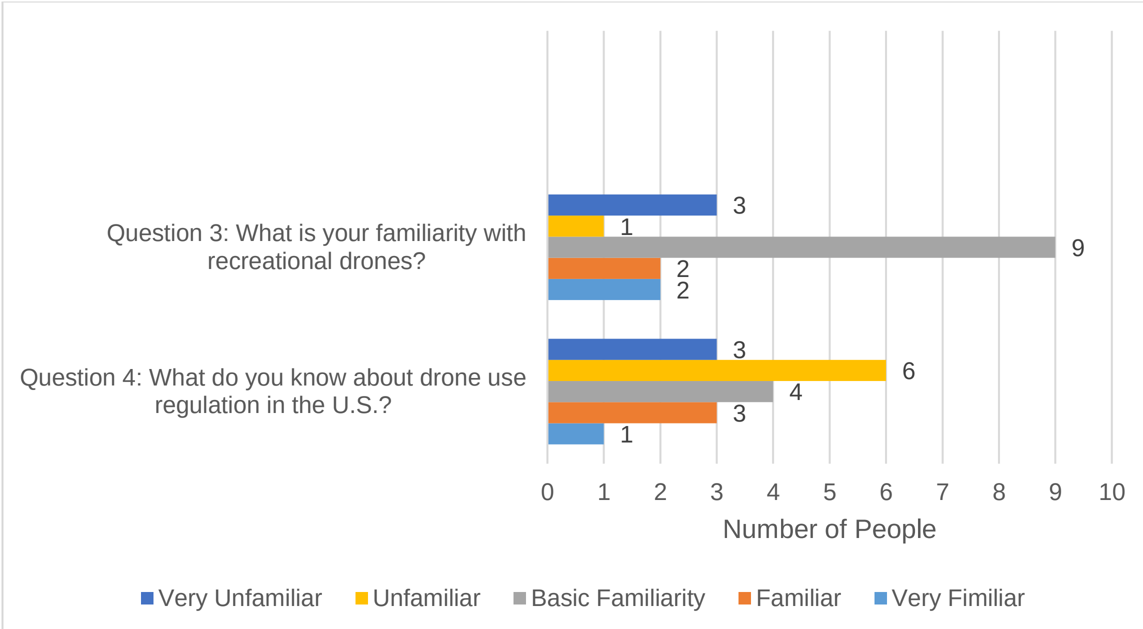

Figure 24 Results of questions 3 and 4 to gauge how much information respondents had before visiting the website on drone use and regulations.

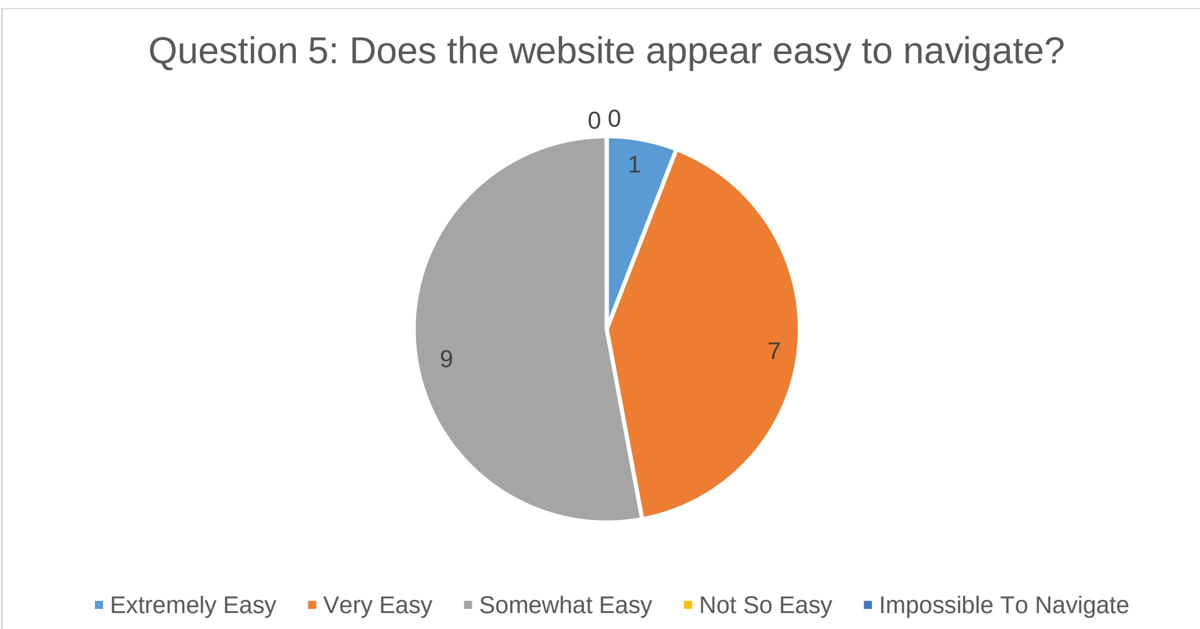

Figure 25 Results of question five, used to assess the ease of use of the website as a whole.

The results for Question 5, shown in Figure 24, recorded how easy the website was to navigate. Although there were no major issues reported in website navigation, 53% of respondents thought that the website was tricky to navigable, pointing to the need to improve the website navigability in future updates. The results for Question 6, summarized in Table 9, show what features could be added to improve the website. Of the 17 respondents, six said that nothing needed to be added and 11 suggested new elements to add to the website and the web-GIS map featured on the website. The responses to this question will be discussed in more detail in Chapter 5 below. The results for Question 7, shown in Figure 26, indicate how effective the web-GIS map was at informing visitors of drone no-fly zones in the state of Maryland. The web-GIS map was able to effectively inform 70% of website visitors of where drone no-fly zones were in the state of Maryland. This result shows that the overall web-GIS map was successful in visualizing the federal and state drone use data on no-fly zones to visitors. In addition, the results for Question 8, shown in Figure 27, indicated that 76% of website visitors found the legend for the web-GIS map clear and concise.

Table 9 The responses to question six of the survey about ways the website could be improved.

Question 6: What Could Be Added to Improve This Website?								
Nothing	6							
Please Specify	11	An address search function	An option to switch views to see legal zones to fly drones	Distances from the centers of airport icons	Just Shade areas with no-fly zones	Easily located search bar, on the map, for specific locations	Larger Title	Ability to enable/disable certain features of the map
Unsure		Legend in Map	Make survey compatible with android devices	Titles and contact information for military bases				

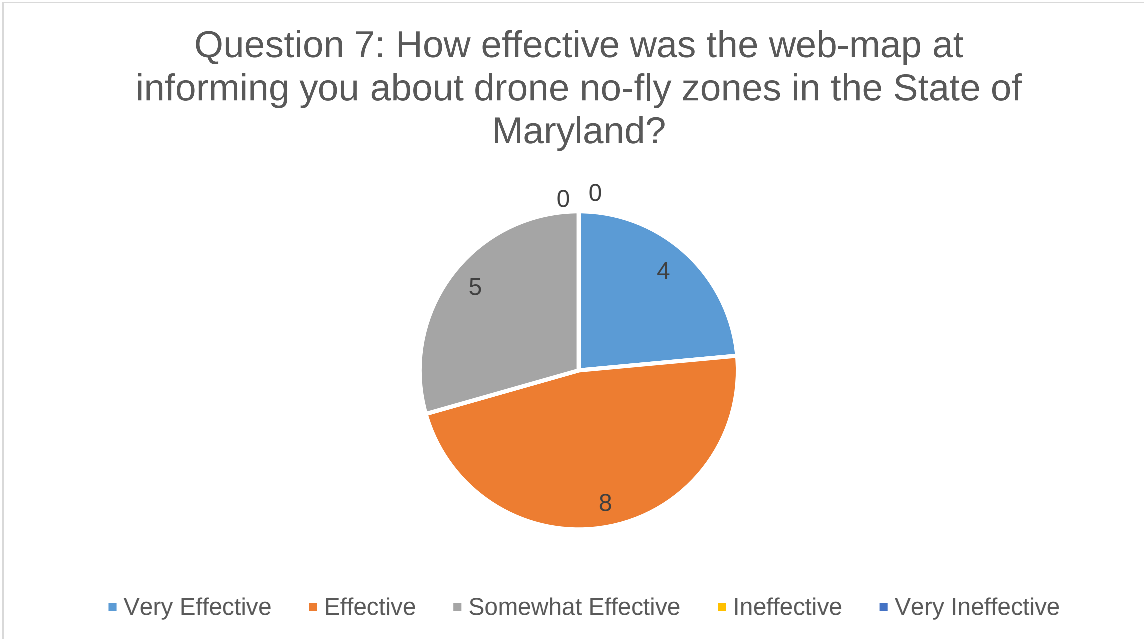

Figure 26 Results of question seven, used to assess the effectiveness of the web-GIS map at conveying inappropriate and appropriate areas of drone use in the State of Maryland.

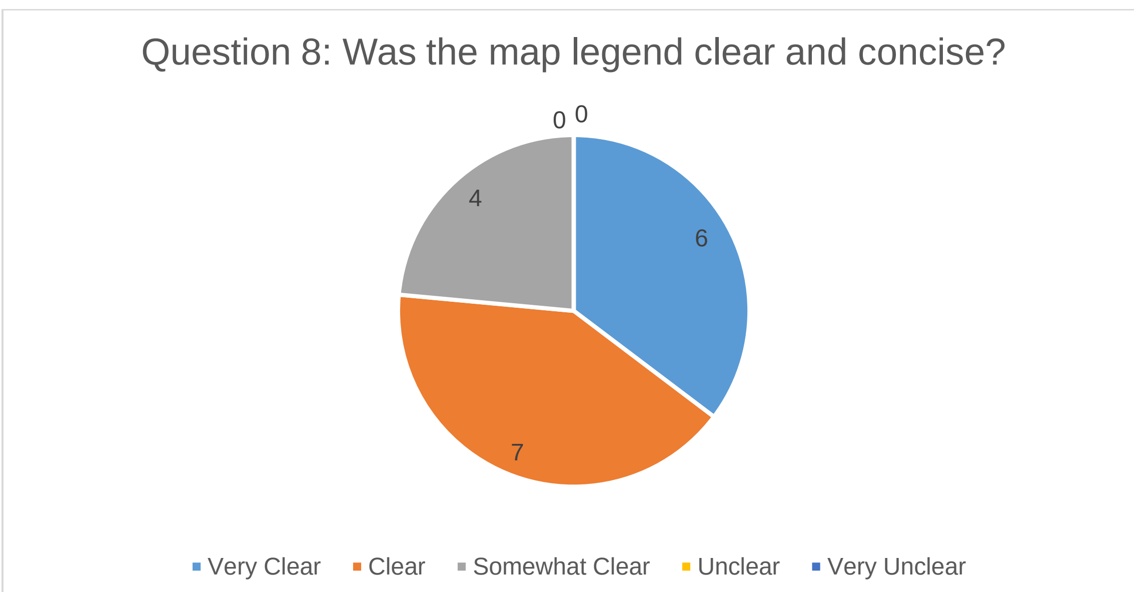

Figure 27 Results of question eight indicating how clear the legend on the website was for the web-GIS map.

The results for Question 9, shown in Figure 27, indicate how much respondents learned about drone use regulation after visiting this website. All 17 respondents (100%) indicated that they signed off the website with at least a little new knowledge about drone use regulation and nine of the 17 respondents (47%) claimed they learned a moderate amount or more. The results for the final survey question, Question 10 shown in Figure 28, reported how many of the respondents would recommend this website to other people interested in drone use regulation in Maryland. All 17 respondents indicated that they would at least consider suggesting this website and web-GIS map to others, and ten respondents (59%) indicated that they would recommend it to others. This question was also very important because it shows that this type of website is in demand for people to learn more about drone use in Maryland.

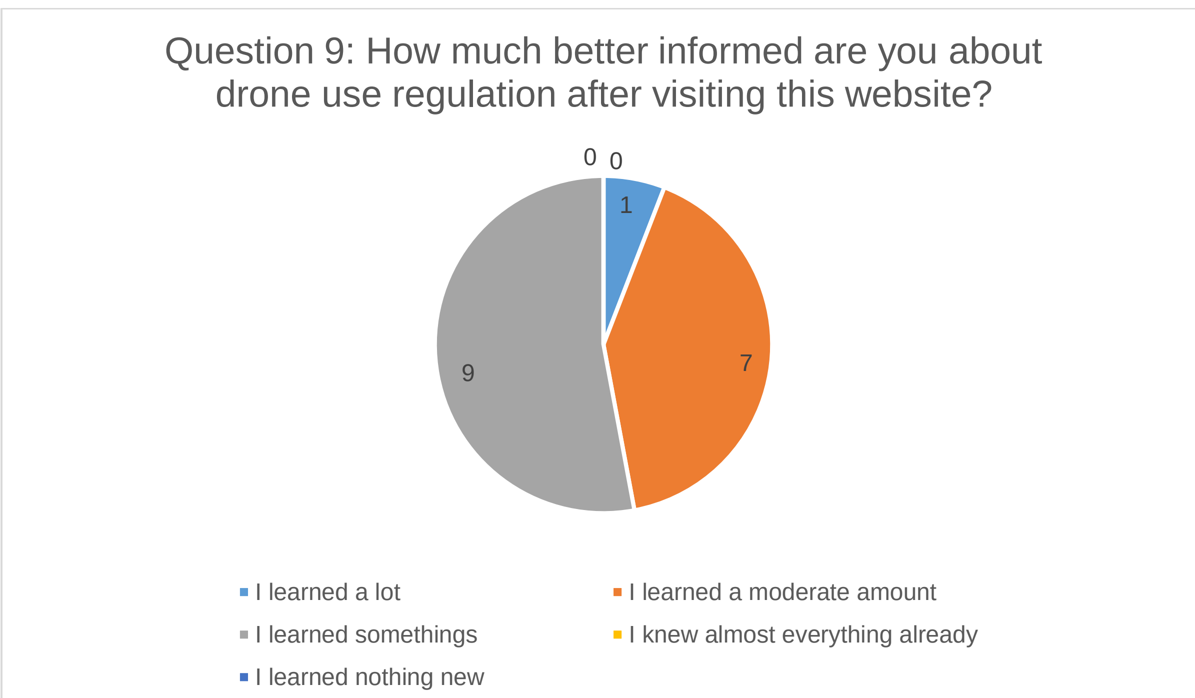

Figure 28 Results of question none indicating how much new information on drone use regulation website visitors left the website with.

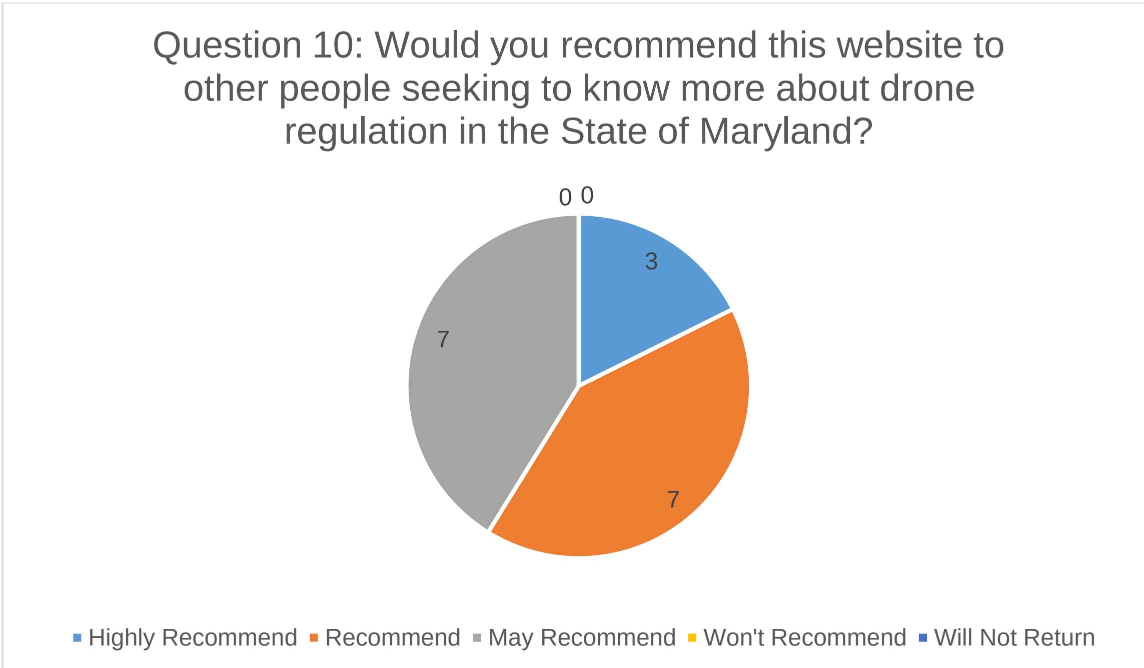

Figure 29 Results of question 10 showing the overall rating of this website and whether or not a visitor would recommend this website to others wanting to know more on drone use regulations in the state of Maryland.

Chapter 5 Discussion and Conclusions

The creation of a geodatabase and web-GIS map to visualize drone use in the state of Maryland led to positive contributions in this field, which are explained in this final chapter. The other topics that will be expounded are the areas for improvement as suggested by the survey results. Finally, future work that could be conducted to improve this research topic will be discussed.

5.1 Advances

Through the course of the construction of the geodatabase and web-GIS map to visualize drone use areas in the state of Maryland, several things were discovered. One was that locating information about airports and their locations is very complicated. Even Maryland's main website (md.gov) does not have a complete list of airports in the state. It does have a list of major airports, but almost none of the other 180 plus airports are listed, even though airport ownership is supposed to be publicly available.

It is important now more than ever in an age with increased consumer drone use to have this information more readily accessible to the public. To prevent accidentally breaking the law by flying a drone within five miles of an airport, drone users need to be able to locate all the airports and heliports in the areas that they wish to fly their drones. This web-GIS map will be the first website that visualizes and provides data about every airport and heliport in Maryland that is still in use. The next thing that this geodatabase and web-GIS map provides to the fields of GIS and drone use is that it is the first state-specific, query-able catalog of drone use GIS data in the U.S.

No other states so far have created a state-specific drone use geodatabase and web-GIS map. This thesis has done just that: It has organized, collected, and visualized the data required to create a state-specific drone use geodatabase and web-GIS map to allow anyone interested in flying a drone to be able to locate appropriate areas in which to do so. Hopefully, other states will be able to use both the geodatabase and web-GIS map created for this thesis to create their own web-GIS maps and geodatabases to organize and visualize the data in a similar way for their state. The final contribution of this thesis is that detailed, step-by-step instructions on what GIS data is required to create a drone use geodatabase and web-GIS map of drone use are provided to other researchers and state organizations that wish to build a similar one. This methodology will allow researchers and state policymakers to save time by building upon the skeleton of this project.

5.2 Survey Suggestions

The web-GIS website's survey has one question, question six, that asks respondents to suggest ways to improve the website and map. Of the 17 respondents, 11 suggested new ways to improve the website and web-GIS map to increase user-friendliness, ease of access, and ease of query in the web-GIS map and geodatabase. The results for this question were shared in Table 10. Of these responses, two were the same and appeared to be feasible to add for a future update to this web-GIS website. The other suggestions were to improve the aesthetics of the map and website. The two responses were both to add search functionality to the web-GIS to allow website visitors to type in an address and locate it on the map. This is explained further in the following section.

5.3 Future Work

There are four main areas that need to be improved to increase ease of use of the geodatabase and web-GIS map of drone use in Maryland. They are the development of a web-GIS map that can search addresses; the inclusion of a map that can update TFRs in real time; the addition of airports that are within five miles of the borders of the state of Maryland; and the inclusion of additional map functions. Through the addition of these four elements, the geodatabase and web-GIS map created for this thesis would be greatly strengthened.

5.3.1 Address Location Search Ability

One of the main issues with the creation of the web-GIS and geodatabase to visualize drone use in Maryland is that users cannot directly query addresses or areas that they wish to fly their drones, like via Google Maps' traditional address lookup. This is partially due to time constraints and also the complicated nature of this type of programming. Eventually, the addition of some address search similar in scope to Google Maps address search service needs to be added to this website's web-GIS to increase the ease of use for website visitors in locating appropriate areas for drone use.

5.3.2 TFR Real-Time Updates

Another area that could be improved upon for the web-GIS and geodatabase created for this thesis is that there is currently no way to update any incidental temporary flight restrictions to the map in a timely manner. This is mainly because the website is maintained only by the author of this thesis. Future updates to this website will attempt to link FAA and sporting event

TFR's to allow drone users to view temporary restricted flight areas in their area in real-time. This will decrease accidental drone trespass once it is implemented.

5.3.3 Neighboring States' No-Fly Zones

Another aspect of the drone use geodatabase and web-GIS map that can be improved upon in future work is the incorporation of airport data from all neighboring states. The current map includes Washington D.C. because it has two locations with no-fly zones that extend seven miles into Maryland. Unfortunately, due to time constraints, other sites in Delaware, Virginia, New Jersey, and Pennsylvania were not included. Over time, however, data from these other states will be added to paint a more complete picture of drone use no-fly zones in Maryland. If other states adopt a web-map and geodatabase like the one created in this thesis, creating drone use visualizations of those states will be very straightforward and will allow a national web-GIS map to be created that flows from one state to the next.

5.3.4 Additional Map Functionality

The final additional web-GIS map function that needs to be added to improve the web-GIS map is a function to turn map layers on and off. Specifically, the ability to turn off no-fly zones to allow web map users to view the map in areas with high no-fly zone concentrations, as illustrated in Figure 30. This could be accomplished in two ways: (1) by allowing users to activate the delineation of no-fly zones when a specific point inside the no-fly zone is clicked; and (2) by allowing the complete layer to be switched on and off with a slider button.

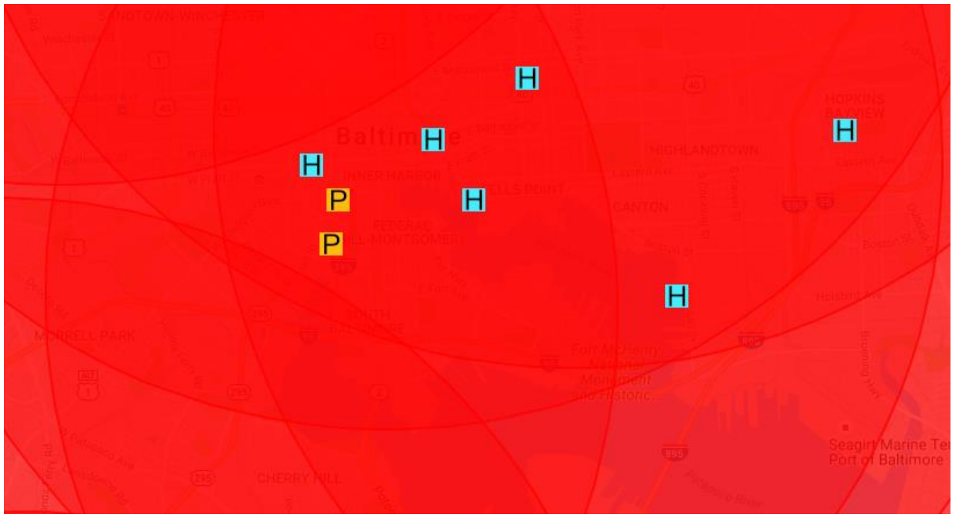

Figure 30 Map showing how the high density drone no-fly zones around Baltimore City prevent the user from viewing the underlying geography.

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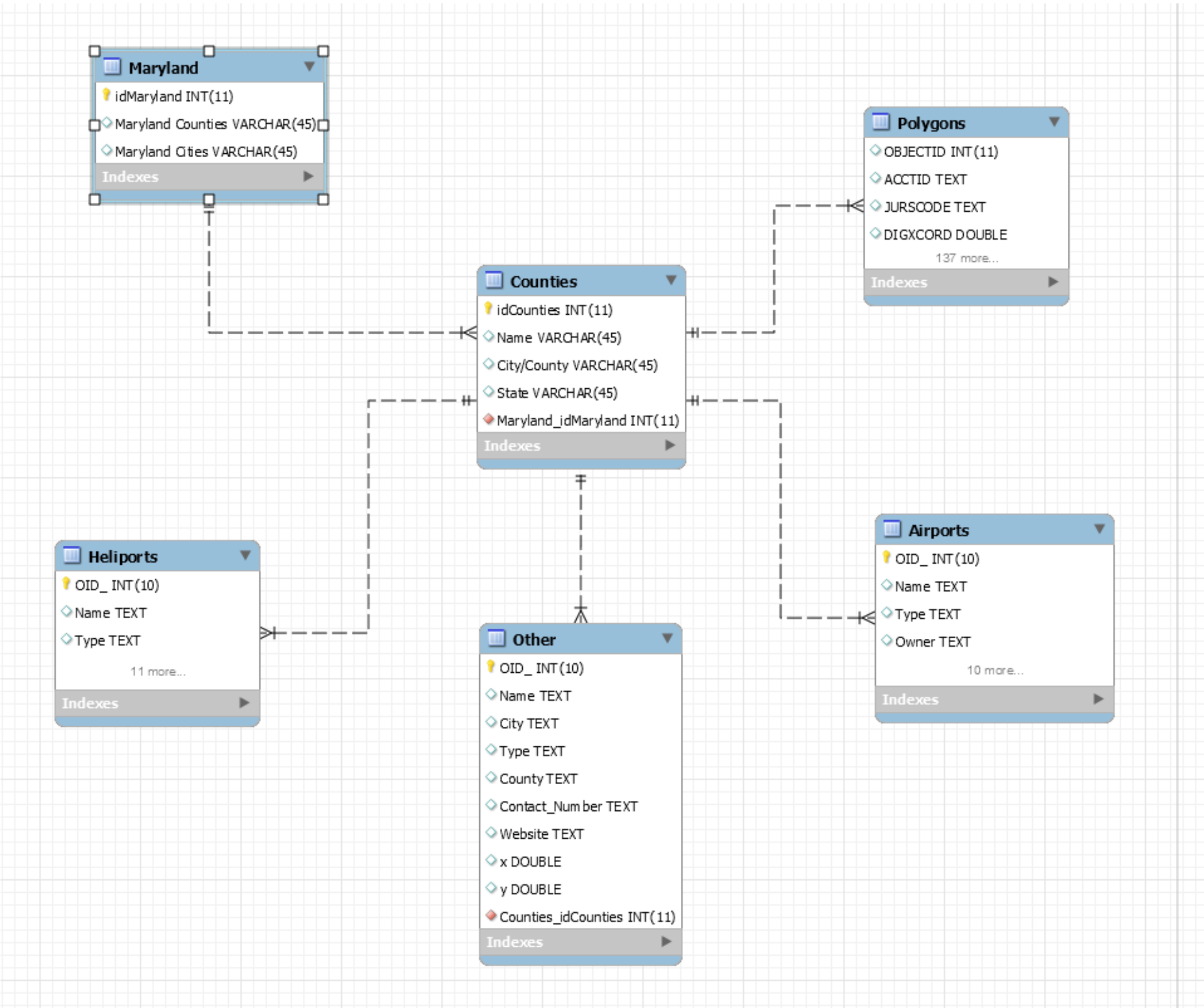
Appendix A: MSSQL Database

The MSSQL database design



Appendix B: JavaScript Code

The web-GIS map code

```
var  markers  = null;
var infoForMarkers = [];

var map = new google.maps.Map(document.getElementById('map'), {
          center: {lat: 39.3630905, lng: -75.8131638},
          zoom: 10
        });

 var shape = {
          coords: [1, 1, 1, 20, 18, 20, 18, 1],
          type: 'poly'
        };



var infowindow = new google.maps.InfoWindow();


var jetImage = {
              url:
'http://www.cyberclockgames.com/brendan/marker_icon.gif',
    // This marker is 20 pixels wide by 32 pixels high.
              size: new google.maps.Size(20, 20),
    // The origin for this jetImage is (0, 0).
              origin: new google.maps.Point(0, 0),
    // The anchor for this jetImage is the base of the flagpole at (0,
32).
              anchor: new google.maps.Point(0, 20)
              };



/************************      Airports        ************************/

      downloadUrl("phpsqlajax_dbinfo.php", function(data) {
        var xml = data.responseXML;
     markers = xml.documentElement.getElementsByTagName("marker");
        for (var i = 0; i < markers.length; i++) {


              var Name = markers[i].getAttribute("Name");
              var Type = markers[i].getAttribute("Type");
              var Owner = markers[i].getAttribute("Owner");
              var Tower_Present = markers[i].getAttribute("name");
              var Website = markers[i].getAttribute("Website");
              var Use = markers[i].getAttribute("Use");
              var Contact_Number =
markers[i].getAttribute("Contact_Number");
              var point = new google.maps.LatLng(
```

```
                parseFloat(markers[i].getAttribute("Lat")),
                parseFloat(markers[i].getAttribute("Lng")));
                var County = markers[i].getAttribute("County");
                var City = markers[i].getAttribute("City");

                //var html = "<b>" + Website + Name + "</b> <br/>" + Owner;
                var html = '<div id="content">'+
        '<div id="siteNotice">'+
        '</div>'+
        '<h1 id="firstHeading" class="firstHeading">'+Name+'</h1>'+
        '<div id="bodyContent">'+
        '<p>'+Website+'<a href="'+Website+'"></p>'+
        '</div>'+
        '</div>';

                infoForMarkers[i] = html;


            drawCircle(map, point, Name);


            var marker = new google.maps.Marker({
              map: map,
              position: point,
              icon: jetImage,
              shape: shape,
              title: Name,
              zIndex: i
            });
    google.maps.event.addListener(marker, 'click', function () {
  infowindow.setContent(infoForMarkers[this.zIndex]);
  infowindow.open(map, this);
        });
      }
      });


/*****************  Shapes *****************/

var kmlLayer = new google.maps.KmlLayer({
          url:
'http://www.cyberclockgames.com/brendan/kmlfiles/parks.kml',
          map: map
        });

    }

    kmlLayer.addListener('click', function(kmlEvent) {
    var text = kmlEvent.featureData.description;
    showInContentWindow(text);
  });

  function showInContentWindow(text) {
    var sidediv = document.getElementById('content-window');
```

```
    sidediv.innerHTML = text;
  }



function drawCircle(map, point, name)
{
       var cityCircle = new google.maps.Circle({
            strokeColor: '#FF0000',
            strokeOpacity: 0.8,
            strokeWeight: 2,
            fillColor: '#FF0000',
            fillOpacity: 0.25,
            map: map,
            center: point,
            radius: 8046.72
          });

           if(name == 'Ronald Reagan Washington National Airport'){
               cityCircle.setRadius(24140.2);
    var cityCircle = new google.maps.Circle({
            strokeColor: '#FFAAAA',
            strokeOpacity: 0.8,
            strokeWeight: 2,
            fillColor: '#FFBBBB',
            fillOpacity: 0.20,
            map: map,
            center: point,
            radius: 48280.3
          });
          }
          else{
               cityCircle.setRadius(8046.72);
          }
};

function downloadUrl(url,callback) {
 var request = window.ActiveXObject ?
     new ActiveXObject('Microsoft.XMLHTTP') :
     new XMLHttpRequest;

 request.onreadystatechange = function() {
   if (request.readyState == 4) {
     request.onreadystatechange = doNothing;
     callback(request, request.status);
   }
 };

 request.open('GET', url, true);
 request.send(null);
}

 function doNothing() {}
```

Appendix C: Survey Questions

Drone Use Map Questionnaire

1. What is your age?
18 to 24
25 to 34
35 to 44
45 to 54
55 to 64
65 to 74
75 or older

2. What field are you in?
Accounting
Government
Customer Service
Marketing
Operations
Human Resources
Sales
Finance
Legal
IT
Engineering
Product
Research & Development
International
Business Intelligence
Manufacturing
Public Relations
Student
Other (please specify)

3. What is your familiarity with recreational drones?
Very Familiar
Somewhat Familiar
Basic Familiarity
Somewhat Unfamiliar
Very Unfamiliar

4. What do you know about drone use regulation in the U.S.?
Very Familiar
Familiar
Somewhat Familiar
Unfamiliar
Very Unfamiliar

5. Does the website appear easy to navigate?
Extremely easy
Very easy
Somewhat easy
Not so easy
Not at all easy

6. What could be added to this website to improve it?
Nothing
Please Specify

7. How effective was the web-map at informing you about drone no-fly zones in the state of Maryland?
Very Effective
Effective
Somewhat Effective
Ineffective
Very Ineffective

8. Was the map legend clear and concise?
Very clear
Clear
Sort of clear
Unclear
Very unclear/ impossible to figure out

9. How much better informed are you about drone use regulation after visiting this website?
I learned a lot about drone regulation
I learned a moderate amount about drone regulation
I learned somethings about drone regulation
I knew the vast majority of drone regulations already
I already knew everything on this website

10. Would you recommend this website to other people seeking to know more about drone regulation in the state of Maryland?
Highly Recommend
Recommend
May Recommend
Won't Recommend
Will Recommend to People to Avoid This Website