

USING GIS TO CREATE AN INTERACTIVE GEOPDF MAPBOOK
FOR THE BIG ISLAND OF HAWAII

A THESIS PRESENTED TO
THE DEPARTMENT OF GEOLOGY AND GEOGRAPHY
IN CANDIDACY FOR THE DEGREE OF
MASTER OF SCIENCE

By

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MARYVILLE, MISSOURI

JUNE, 2009

INTERACTIVE GEOPDF MAPBOOK

Using GIS to Create an Interactive
GeoPDF Mapbook for the Big Island of Hawaii

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Abstract

GeoPDF is a new file format with geospatial information developed by TerraGo Technologies that was created to disseminate data and information for people in the field or residents of a community. The purpose of the study is to provide an interactive geospatial product as a GeoPDF to scientists, residents, and tourists of the Big Island of Hawaii. One product was created that delivers information displaying restaurant and tourism data, and another product provides hazard and emergency response data. The goal is for a GIS specialist to create geospatial products that can be viewed and manipulated by non GIS professionals through the use of Adobe Reader. This means the user has to have Adobe Reader installed on their computer as well as the TerraGo toolbar (formerly known as GeoPDF toolbar). Users have the ability to turn on and off layers, insert markups and comments, and create shapefiles. The final products contain a large amount of information that can be used by anyone who has access to a computer and the internet. It is a great way to exchange information within a community or to disperse information to a group of people.

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CHAPTER 1

INTRODUCTION

GIS is a rapidly growing field that has many applications, including military operations, emergency planning and response, homeland security, and geological processes. The geospatial data and tools available on common personal computers in commercial GIS software are really amazing. Every day new programs or extensions are developed that enable GIS users to expand upon their uses for GIS. For example, IWANE Laboratories based in Japan has developed a Desktop 3D Video GIS software that allows GIS analysts to view 3D data with a 360 degree view in real time. It uses tracking technology to get highly accurate 3D coordinates at any pixel (IWANE Laboratories LTD. 2008).

Some common GIS software, such as ArcGIS, ERDAS IMAGINE, MapInfo, MicroImages, and Intergraph GeoMedia, are used to create and manage geospatial data, process and view imagery, build 3-D models and fly-throughs, and create standard map products. These GIS software packages are usually only purchased by government agencies, the military, corporations, or universities due to the cost of the software and licenses being very expensive. Therefore, most individuals could not afford to purchase it for their personal computers and the use of GIS is mostly limited to professionals who use it for their occupation.

There is an abundance of geospatial data that are available for download through the Internet such as transportation data and commercial imagery. Data such as these can be found on government or university websites. A GIS Analyst can easily download

gigabytes of georeferenced data and then perform complex spatial analyses by combining this free data with data they collect. The only problem is that this data can only be used by people who have GIS software or capabilities. There are resources like National Map Viewer to view and download various types of GIS data, but the user would first have to have knowledge of the website and then have Internet connectivity to view the data. This type of alternative could seem overwhelming for someone who isn't familiar with this type of data viewing capabilities. The data are available for download through National Viewer, but GIS software would be needed to view the data. Another way to organize and manipulate these data for sharing is printed maps, but there were several limitations of printed maps.

First, they are static and changeable only by the GIS analyst. They were originally produced with a specific theme forcing the analyst to decide what they thought the appropriate layers were to display. Second, the user will not be able to view different combinations of layers. Third, there is no efficient way to update, markup, or annotate the desired information to pass along to others who needs the data. The purpose of this research is to demonstrate how GIS software can produce an interactive geospatial product that can be viewed and manipulated by a user who does not have GIS software or knowledge.

A recent innovation in geospatial information sharing is the inclusion of georeferenced Adobe Acrobat and Adobe Reader documents in the Portable Document Format (PDF). Third party companies such as TerraGo Technologies have provided tools (TerraGo Desktop, formerly known as GeoPDF Toolbar) for using coordinate information in a PDF file, such as being able to import and export geospatial data

(TerraGo Technologies 2008a). They have also provided add-on tools that extend the Adobe Reader program so it can use the coordinate information in these georeferenced PDF (GeoPDF) documents. Coordinate information for the cursor's location in the document can be displayed, and GPS tracking and measuring tools are available. Adobe has also added some native geospatial support with an Object Data Tool and a Geospatial Location Tool built into Adobe Reader 9.0 and up. These features add more versatility to the GeoPDF by enabling the user to obtain additional attribute information about the layers. A built-in Layer Manager allows one to toggle different spatial layers on or off to change the displayed map (Moran 2008).

TerraGo Technologies also developed TerraGo Publisher Suite for ArcGIS (formerly known as Map2PDF), which allows users to import data from ArcGIS and create GeoPDFs (Table 1). TerraGo Composer (formerly known as Map2PDF for Acrobat) enables the user to take multiple forms of data (GeoPDF, KML, vector, or raster) and add business context for personal uses (TerraGo Technologies 2009). Other GIS software companies like ESRI (ESRI 2008a) and MicroImages (MicroImages INC. 2009) have supported this new capability by making it relatively easy to render PDF documents, including complex poster layouts, with useful coordinate information. New tools have been created that fall outside the traditional GIS areas such as GeoTrack which can display the current position of an attached GPS device on a GeoPDF. This extension of the leading general publishing format can have some very useful applications for scientists in the field or recreational purposes.

Table 1: Components of TerraGo

<p>Publisher for ArcGIS – Intended for GIS Analyst (formerly known as Map2PDF)</p> <ul style="list-style-type: none">•Exports map layout to a GeoPDF file•Embeds projection coordinate systems within the PDF•Maintains layers within the PDF•Enables attribute search with Acrobat Object Data•Gives map users the ability to find and zoom to attribute data•Allows map users to measure distance and bearing•Available for 9.x and above
<p>TerraGo Composer – Intended for GIS Analyst (formerly known as Map2PDF Acrobat)</p> <p>TerraGo Composer Highlights</p> <ul style="list-style-type: none">•Converts any PDF-based map to a georegistered GeoPDF file•Batch georegistration allows users to automatically convert existing PDF map files to GeoPDF format•Indexing lets users create an overview index with hyperlinks and bookmarks•Adjacency hyperlinks are added•GeoJavaScript lets users create custom applications that interact with GeoPDF files via geospatially-enabled JavaScript•Tools assemble maps from multiple map sources into one GeoPDF•Conversion and compression allow users to incorporate many files into one map collection•GeoMarking allows end users to markup maps and collaborate <p>New Features</p> <ul style="list-style-type: none">Combine multiple GeoPDF files into layered PDF documentsComment, share and incorporate updates back into GIS databasesImport shp, KML and GPX filesExport shp and KML files
<p>TerraGo Desktop – Intended for Non-GIS User/Adobe Reader (formerly known as GeoPDF Toolbar)</p> <ul style="list-style-type: none">•Ability to view maps with multiple coordinate displays•Measures length and area•Turn layers on and off and search map attributes.•Users can create notes redlines and markups or attach images or other data from multiple sources•Redlines and comments can be exported to an ESRI shapefile for incorporation back into a geospatial data repository.

The purpose of these extensions and tools is to provide interactive geospatial products being a GeoPDF to non GIS professionals or people who do not have access to GIS software. These documents can be viewed with Adobe Reader which is a program that most people already have installed on their personal computers. The familiarity of Adobe gives TerraGo the greatest opportunity to provide information to the wider potential customer base (Maclenan 2007). The TerraGo toolbar gives the user powerful

mapping functionality to locate, display, freeze and unfreeze coordinates, display multiple coordinate systems, and measure distance, and all of these functions can be used in Adobe Reader. The analyst using TerraGo Composer for Acrobat has the ability to GeoMark enable the GeoPDF; this will give the end user the ability to use TerraGo Desktop in Adobe Reader. Users can insert user markups, add annotation, even directly export updates to ESRI shapefile or KML (Google Earth) for better managing activities on the ground and improve communications. People using Adobe Reader will be able to activate and deactivate the layers and can create new shapefiles but they don't have the ability to modify the existing shapefiles as an analyst can in ArcMap. The user has to have the TerraGo Desktop toolbar (GeoPDF toolbar) installed for Adobe Reader and the user will be able to import and export familiar GIS data formats. This type of geospatial technology was intended for transportation officials, field personnel, and engineers on the scene of natural disasters (TerraGo Technologies 2008b).

The United States Army Engineer Research and Development Center's Topographic Engineering Center (ERDC/TEC) has developed GeoPDFs of several countries making them available as DVDs. These DVDs include map sheets of areas all over the world as well as the Urban Tactical Planner data (UTP) and route studies in the GeoPDF format to distribute to soldiers (Caputo 2007). GeoPDFs have been used to simulate possible storm surge scenarios similar to Hurricane Katrina and Hurricane Rita (Mills and Curtis 2008), to demonstrate the potential damage the storm could cause, if the storm had made landfall in another area of Louisiana. TerraGo Technologies and GeoEye, Inc. have teamed up to produce high resolution imagery in GeoPDF files for the emergency workers and relief organizations battling wildfires in southern California

(TerraGo Technologies 2009). The data for this natural disaster are published at TerraGo Technologies' web site for download free of charge.

1.1 Research Objective

The key concept of the GeoPDF is that it is a geospatially referenced PDF file that does not require GIS software to view the product. Little or no experience using GIS software is required to use the TerraGo Desktop (GeoPDF toolbar) software for Adobe Reader. The GeoPDF is viewed in Adobe Reader, which is common software that approximately 700 million people currently use to view PDF files. The intent of GeoPDF is to reach the audience with a technology they are already familiar with (Wuthrith 2006). Shapefiles and KML files can be created in Adobe Reader with a GeoMark enabled GeoPDF file, which can then later be imported into GIS software.

The primary objective of this study was to provide a personalized geospatial product to residents of Hawaii, tourists, geologists, and emergency response teams. The product will become personalized to the user because they will decide what data layers they want displayed on the map. By offering a variety of data this product could target other users as well, such as public officials, real estate agencies, and insurance companies which could all potentially benefit from the GeoPDF. Because the GeoPDF was intended for people who possess limited or no GIS experience, the range of users that can benefit from this research greatly increases. For example the residents of the Big Island of Hawaii have to deal with possible injury or destruction due to an active volcano. One example of how the public could benefit is that important information about active volcanoes in the Kilauea areas could be distributed with a GeoPDF.

The final products contained hazard zonation data, along with other pertinent data such as hospitals, main transportation routes, shelters, and tourist attractions. The user was able to activate and deactivate layers, query attributes, write notes, and display coordinates. The products also contained hyperlinks and bookmarks for people to use. It was in a format that can be easily printed for professionals to take in the field. Overall, it was a great way to share geospatial data between GIS professionals and non GIS users. There are other options available for viewing geospatial products and data, but GeoPDFs do not require users to learn new software or become experienced with unfamiliar file formats.

Google Earth has become a very popular tool for viewing areas with imagery at a large scale, but the user would have to be familiar with downloading and installing software, and then the user would have to have an understanding of KML files and what is involved to convert data into KML files so modifications or updates can be viewed in Google Earth (Mills and Curtis 2008). This would also mean that the user would have to have continual access to the internet as well.

The objective was to create personalized GeoPDFs for the residents and tourists of Hawaii. The objectives were met by creating several easy-to-use products with data that could benefit a variety of people.

This thesis is divided into the following chapters:

Chapter One

- States the research objective

Chapter Two

- Addresses the need for geospatial data

- Defines GeoPDF

Chapter Three

- Describes the study area and data used to create GeoPDFs
- Describes the GeoPDF creation process, including the gathering and organization of the data

Chapter 4

- Identifies users of the Hazard and Tourism GeoPDFs
- Presents detailed descriptions of GeoPDFs

Chapter 5

- Addresses limitations of the project and establishes possible future applications for the GeoPDF

CHAPTER 2

RESEARCH BACKGROUND AND LITERATURE REVIEW

2.1 The Demand of Geospatial Information

The uses for GIS in business and government are established and well known. Any organization that provides services for customers who manage natural resources or property operates in the physical world and can benefit from a comprehensive mapping system. Forster (2000) discussed how lower computer costs, widespread data availability, improved GIS software, linkages to large databases, and data distribution systems increase the uses of geospatial technology. There are many ways that companies with geographically widespread operations can benefit from these advances, especially for operations planning and logistics.

The popularity of Google Earth (and other web based mapping systems) demonstrates that there is a strong demand for casual geospatial information browsing if the information can be organized and made easily accessible. Google Earth has raised the public's awareness of geospatial information and created a demand for the ability to manipulate that published information for their own use. "In the three years since its public unveiling in 2005, Google Earth has become a mainstay of students, travelers, businesses, and researchers seeking a one-stop place for posting or finding information about the world – on topics as diverse as hotels and hiking trails, species' ranges and climate data" (Revkin 2008).

Geospatial information must be collected and organized before it is needed in a crisis situation. For example, if a natural disaster occurs, responders need to have

products readily available to reduce the amount of time before assistance can begin.

Responders have to be aware of the situations and obstacles they may encounter. A well designed GIS needs to be organized and accessible especially if analysts need to be able to access it in a hurry. One good example of this can be seen when emergency response to an event is required. Making interfaces for GIS data access, the quality of data available, and the addition of up-to-date data are important. Better data integration with populations, social interactions, data quality ratings, and a way to get the data organized and presented to people who need it are issues that need further research (Cutter 2003).

People want to view products that are easily interpreted and that can be customized based on their own preference or needs. Posting organized GeoPDF's on the Internet could provide an alternative solution to the standard map that is usually in the form of a low resolution image file. Users can insert markups and comments on the GeoPDF; this can be considered an alternative form of communication among the general public. For example, geologists can add markups for current volcanic activity locations, and tourists can insert markups for attraction points. The GeoPDF map book has several data layers to choose from so users are able to customize their own product. Hyperlinks in the GeoPDF can be linked to other GeoPDF files, such as orthoimagery, to provide greater detail in areas of interest. Users will be able to print the products to carry into the field or while travelling if necessary.

2.2 GeoPDF

GeoPDF was originally developed by the National Geospatial-Intelligence Agency (NGA), in conjunction with private industry, to provide map display technology

in battle command. The previous map display format, ARC Digitized Raster Graphics (ADRG), provided a clear view of the scanned map in computer displays, but file sizes were so large that few maps could be loaded on a single compact disc (CD). Compressed ARC Digitized Raster Graphics (CADRG) was developed as a new file format using compressed ADRG. The compression reduces the clarity of the data, but the file sizes are significantly reduced, allowing more background data to be loaded on a CD. CADRG files are much smaller than ADRG but the digital map display becomes blurry as the user magnifies an area for more detail (Bergman and Caputo 2006). GeoPDF improves military digital map display technology and takes GIS to the next level. The files are relatively small (most range from 2 to 20 megabytes per map) and the digital display on the computer remains crisp and clear as the user zooms in for detail. The GeoPDF maps can also be printed on letter-size paper (not to scale) or printed to scale on a plotter. It also makes GIS functionality possible without even having to use GIS software when the end product is completed.

The GeoPDF was created to more quickly and effectively deliver mapping data to field workers and the community. The need for geospatial data and products has rapidly grown, and the products are required by a variety of federal agencies and professionals. A majority of the fields that have been recently introduced to GeoPDFs do not have experience with GIS or the GIS software that is required to produce geospatial products (TerraGo Technologies 2008b). GeoPDFs have given people in the field the ability to receive geospatially referenced products without having to use sophisticated software. Finding which professional areas will benefit the most from the GeoPDF shouldn't be viewed as a challenge but as an opportunity to find new users that can benefit from this

type of product. The military was one of the first users of the GeoPDF, and the increase in users has quickly expanded from there. The USGS uses TerraGo software to convert quad sheets into GeoPDFs, but their next release of these GeoPDFs will include thirty-seven layers of data which users can query for names and features.

There are numerous benefits of creating a GeoPDF as opposed to a standard map. A standard map usually only shows limited amount of information. The user will only see information that the analyst thinks is relevant. For example, if there is a hazard map posted on a web site it is typically just an image showing different hazard zones, there usually isn't any additional information associated with it that might be important for people to know (Figure 1). With a GeoPDF a user can view the same product as long as

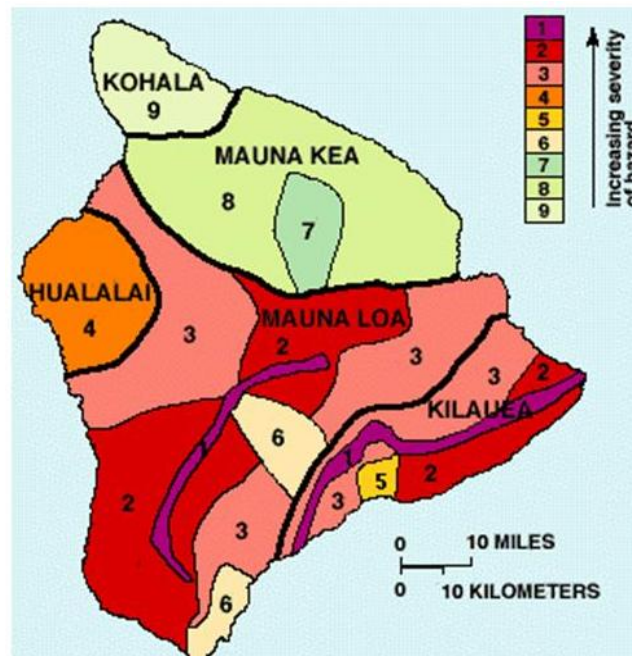


Figure 1: Hazard Zonation Map

Source: Hazard Zonation map originally created in 1974 by Donal Mullineaux and Donald Peterson of the U.S. Geological Survey and revised in 1987.

the layers are present within the GeoPDF, as well as additional information provided, such as text documents, without GIS software or Internet capabilities. The only program that is needed to view the document is Adobe Reader and a small free plug in from TerraGo Technologies. The 4.1.2 version of the TerraGo Desktop (formerly known as GeoPDF toolbar) is the latest release from TerraGo Technologies. This version is compatible with Adobe Acrobat and Adobe Reader versions 7.x, 8.x, and 9.x.

The GeoPDF has many applications, but for this study the targeted audience was residents, scientists, and tourists of the Big Island of Hawaii, which is famous to the world for its volcanic activity and beautiful beaches. The two themes that the GeoPDFs were based on were volcanic hazards and tourism information associated with Hawaii. The study described the process of creating a GeoPDF mapbook for the Big Island including the data assembly process in ArcMap, converting data into GeoPDF, and finally how to use the GeoPDF tools in Adobe Professional to create hyperlinks to other products and enabling for GeoMark, which gives users the ability to use the GeoMark functions. It also explained where users can go to download the GeoPDF toolbar for Adobe Reader, and described what tools are associated with the toolbar and how they can be used.

Currently one of the biggest users of GeoPDFs is the United States Army. Since 2004 professionals at the United States Army Corp of Engineers (USACE), Topographic Engineering Center (TEC) are creating map books for areas of interest within U.S. military occupied countries, including Afghanistan and Iraq (Caputo 2007). These products allow soldiers who do not have access to GIS software to view geospatial products with hyperlinks to commercial imagery. It allows soldiers to turn on and off

layers that are of interest to them. Because these map books are in a PDF format, they can be easily printed from a standard printer and disseminated to the soldiers to use on missions.

GeoPDFs are also being used for emergency preparedness. The Florida Division of Emergency Management has created GeoPDFs for most counties within the state of Florida that display hurricane evacuation zones and routes and the potential for flooding. These products can be easily viewed and downloaded through Florida Disaster Map Request forum by Florida residents. The foundation that makes GeoPDFs so valuable when dealing with emergency management and preparedness is that Internet connections are not mandatory. Data are packaged and used without Internet connections, but the users can make notes and mark locations, even import GPS locations with field data, on the maps. Once the Internet connection is available, the users can easily communicate and transfer data to others through GeoPDF (TerraGo Technologies 2008b).

GeoPDFs also have the potential to manage coal mining permits. With potentially thousands of pages covering a variety of technical issues as mandated by Surface Mining Control and Reclamation Act (SMCRA) regulations, GeoPDF can provide easy access and an organized file format (Timmins and Gura 2008). GeoPDF has also played an important role for the Department of Transportation. It has been helpful for managing critical infrastructure, maintenance, and accident and traffic reporting (TerraGo Technologies 2008).

Both vector and raster information can be easily converted into GeoPDF. For vector GeoPDF, GIS data is input directly into GeoPDF format and can be combined with geo-referenced raster data. The data are stored in layers and can include hyperlinks.

For raster GeoPDF, paper maps can be scanned, or existing JPEG/TIFF files can be used, which are then saved in a PDF format and georeferenced using TerraGo tools in Adobe Professional. The users can also convert data from GeoTIFF, Multi-resolution Seamless Image Database (MrSID), National Imagery Transmission Format (NITF), ADRG or CADRG. The advantage of using raster GeoPDF over other image formats is the storage size. Based on project examples conducted in Seoul, for a scale of 1:50,000 scanned Topographic Line Map (TLM) in 300 DPI resolutions, it requires 312 megabytes in uncompressed GeoTIFF format, 10 megabytes in MrSID, 9.7 megabytes in JPEG, 8.8 megabytes in TIFF/ZIP, but only 5 megabytes in GeoPDF format (Caputo 2006). Therefore, the users can easily save several map layers (vector or raster) or even satellite images on one single CD or DVD. It is a great advantage for field work and communication between different agencies.

Mills and Curtis (2008), and Maclenan (2007) were very optimistic of the positive way in which GeoPDFs have impacted people at the community level. Soldiers who have had no previous GIS experience now find GeoPDFs an imperative tool that is essential in completing the mission. Soldiers can use the TerraGo software to connect to a GPS unit which can be used to track their movement on the GeoPDF. The article written by Mills and Curtis (2008) also concluded this is a great tool to use for emergency response because the data can be prepackaged and the Internet would not be a requirement unless users want to send notes about the products among each other. Overall, there was an agreement that GeoPDFs are a great tool for introducing a way to get involvement within the community.

The strength of GeoPDFs described in previous research is the ability to disseminate data (Mills and Curtis 2008). Mills and Curtis (2008) reported ways in which GeoPDFs are currently being used, and they also went into depth about how these tools can help or affect people outside the targeted range. They focused on the need to involve the community as a whole, especially in times of a natural disaster (Mills and Curtis 2008). The previous reports (Mills and Curtis 2008, Maclenan 2007) did not go into much detail in regard to future uses for the software. One article touched on fields where GeoPDFs might be useful, but if there is not any further research being conducted or applied then there are no results for opinions to be based on (Mills and Curtis 2008). GeoPDFs are fairly new so the number of articles available was limited. The geographic community should provide more detailed articles on agencies or professionals that currently use GeoPDFs and how the GeoPDF affect their daily mission.

The general conclusions about GeoPDFs are that they are a great geospatial information dissemination tool. There are some limitations to GeoPDFs, such as the user only being able to view a predetermined data set, but with the Google-Map-It option Google Imagery can be displayed in the map. It is an option that can be used by the end user in Adobe Reader. Mills and Curtis (2008) addressed that map dissemination tools and interactive technologies do have some limitations, such as users not being able to input GIS data, but newer versions of the software are already available that address these issues. If the community uses these tools they should be provided basic information about using the tools and data correctly.

CHAPTER 3

CONCEPTUAL FRAMEWORK AND METHODOLOGY

GIS is a fast growing field with a variety of applications constantly being developed. GIS conferences are held throughout the year to keep companies and GIS professionals updated on the most recent developments involving GIS software. A variety of ways are available to provide geospatial data to non-GIS users in applications such as GoogleEarth and portable GPS units. The focus of this study was to develop a geospatial product or interactive map for the public that was produced by GIS software, but GIS software and expertise are not a requirement to use the product. Adobe Reader is needed to view the products, but this is software that most people already have installed on their computers. This research focused on developing two geospatial products as hazard and tourism GeoPDFs.

3.1 Study Area

The study area was the Big Island of Hawaii (Figure 2). Kilauea and Mauna Loa are the two major active volcanoes on this island. The Big Island is a shield volcano which contains five volcanoes, but Kilauea is currently the most active volcano in the world (U.S. Geological Survey Hawaiian Volcano Observatory 2007). The Hawaiian Islands were formed by a process known as Hot Spot Volcanism. In the Hawaiian language Kilauea means “spewing” or “much spreading.” Lava flows are the primary hazard on the Island of Hawaii. Some other hazards include tephra, volcanic gases,

explosive eruptions, ground cracks and settling. Other types of hazards that plague the Hawaiian Islands include tsunamis, flooding and hurricanes.

The Hawaiian Islands have a population of approximately 1.2 million people (U.S. Census Bureau 2006), and are known for their year round mild climate and beautiful beaches. Hawaii produces coffee, macadamia nuts, cane sugar, pineapple, and bananas, but the main source of outside income for the islands is tourism. The Island of Hawaii is the youngest of the islands with the age of the rock less than 23,000 years old (U.S. Geological Survey Hawaiian Volcano Observatory 2007).



Figure 2: The Study Area

Kilauea is located on the southeast flank of the island with a height of 4,091 ft. Mauna Loa is located to the west of Kilauea. Mauna Loa has a much greater height at 13,677 ft. It has had thirty-three historical eruptions with the estimated age of the first eruption between one million and 700,000 years before present. Mauna Loa last erupted March 24, 1984. Kilauea began to form 300,000 to 600,000 years ago and has been active ever since. The lava flows from Kilauea often reach the ocean. Although Kilauea is known mostly for its gentle eruptions, it has had large explosive eruptions in the past. In 1790 Kilauea had a dangerous eruption that killed several people near its summit. In 1924 before Kilauea erupted, there were several earthquakes, ground cracking, faulting, avalanches, and coastal subsidence. Soon after, there was an explosion that caused rock fragments weighing 400 pounds to be ejected 200 feet. Several other large fragments were ejected up to 900 feet from the rim. This type of activity lasted for about a week. Then on May 18, 1924, the worst explosion occurred. Large rock fragments were ejected along with scalding hot mud that took the life of a photographer. The surrounding towns were evacuated prior to this eruption, most likely saving lives. In 1990 lava flows destroyed the towns of Kalapana and Kaima, Kaima Bay, and Kalapana Black Sand Beach. Lava also destroyed a huge section of State Route 130 which can no longer be traveled. This is an incredible sight and should be seen when travelling to the Big Island of Hawaii (U.S. Geological Survey Hawaiian Volcano Observatory 2007).

Currently Kilauea is active at two locations. At the summit, ash and elevated amounts of sulfur dioxide continue to erupt from the vent. Lava is continuing to erupt from the TEB (Thanksgiving Eve Breakout) vent area and flows through the lava tubes to the ocean.

Another hazard that Hawaii deals with are hurricanes. In 1992 a category 4 Hurricane named Iniki struck the Big Island of Hawaii and caused over 1.8 billion dollars worth of damage. This storm caused six deaths and destroyed over 1400 homes (Wikipedia 2009). Hawaii is definitely not safe from hazards and the damage they cause. Furthermore, Hawaii is a vacation destination for people all over the world.

Tourists search to find the best beaches the islands have to offer, as well as the abundance of activities that Hawaii has. Hawaii has the Volcanoes National Park, as well as deep sea fishing, and scuba diving, and offers a variety of restaurants and lodging. Because of the popularity of Hawaii it is imperative to have products that can inform people of the dangers that exist but also of the activities that are available when on the island.

3.2 Description of Data

The research included information and data from the following sources. The data presented were the most recent data that were available in Fall 2008. The base map was created with data from the ESRI Sample Data (ESRI, 2008b). The coordinate system used for the base map was the Geographic Coordinate System World Geodetic System 84 because the Hawaiian Islands cover a large geographic area, and this reference system is the standard reference system used in cartography. The hazard map and the tourism map contained data from the Hawaii Statewide GIS Program website (<http://hawaii.gov/dbedt/gis/>), and also contained shapefiles that were created from coordinates that were collected using Google Earth (<http://earth.google.com>). The projection that was used for these products was the North American Datum 1983

Universal Transverse Mercator Zone 5 because that was the projection of the shapefiles that were downloaded. The cities shapefile had to be created because the ESRI shapefile did not contain all of the cities that needed to be displayed. The digital orthophoto quadrangle (DOQ) was downloaded from the U.S. Department of Agriculture (<http://www.fsa.usda.gov/FSA/>) Google Earth snapshots were used to fill in the areas where there was not any DOQ coverage.

Base Map (GCS WGS 1984)

Shaded Relief - ESRI Sample Data (ESRI, 2008b)

Continents- ESRI Sample Data (ESRI, 2008b)

Hazard Map (NAD 1983 UTM Zone 5)

Hazard Zones – Hawaii GIS Program (Office of Planning 2008)

Volcano Boundaries – Hawaii GIS Program (Office of Planning 2008)

Emergency Shelters – Hawaii GIS Program (Office of Planning 2008)

Hospitals – Hawaii GIS Program (Office of Planning 2008)

Volcanoes – ESRI Sample Data (ESRI 2008b)

Roads – Hawaii GIS Program (Office of Planning 2008)

Landsat – Hawaii GIS Program (Office of Planning 2008)

Cities – Shapefile created from coordinates from Google Earth

Evacuation Routes – Hawaii GIS Program (Office of Planning 2008)

Tourism Map (NAD 1983 UTM Zone 5)

Restaurants – Shapefile created from coordinates from Google Earth

Hotels – Shapefile created from coordinates from Google Earth

Beaches- Shapefile created from coordinates from Google Earth

National Parks – Hawaii GIS Program (Office of Planning 2008)

Scuba Diving - Shapefile created from coordinates from Google Earth

Nightlife – Shapefile created from coordinates from Google Earth

Imagery (NAD 1983 UTM Zone 5)

Digital Orthophotos (United States Department of Agriculture 2004)

Google Earth Imagery Snapshots (No Projection)

U.S. Census Bureau

2006 Population Data (United States Census Bureau 2008)

3.3 Creating GeoPDFs

Figure 3 outlines the basic steps that were conducted during the research. Further research continued throughout the period the products were being produced. Even before data were acquired it was necessary to decide who the target audiences were and what type of data and products would be beneficial. The target audiences for these products were residents and tourists of the Big Island of Hawaii. There were a total of five GeoPDF products from this research. One of them was an orientation GeoPDF of the Hawaiian Islands with hyperlinks to both the Hazard GeoPDF and the Tourism GeoPDF. The hazard GeoPDF focused on the hazards associated with the Big Island such as lava flows and tsunamis. The tourism GeoPDF focused on tourists and information that might be useful when visiting a new place such as hotels and activities. These were the criteria to determine what data needed to be acquired to create the products. The Tourism GeoPDF had hyperlinks to two GeoPDF image maps, one of Hilo

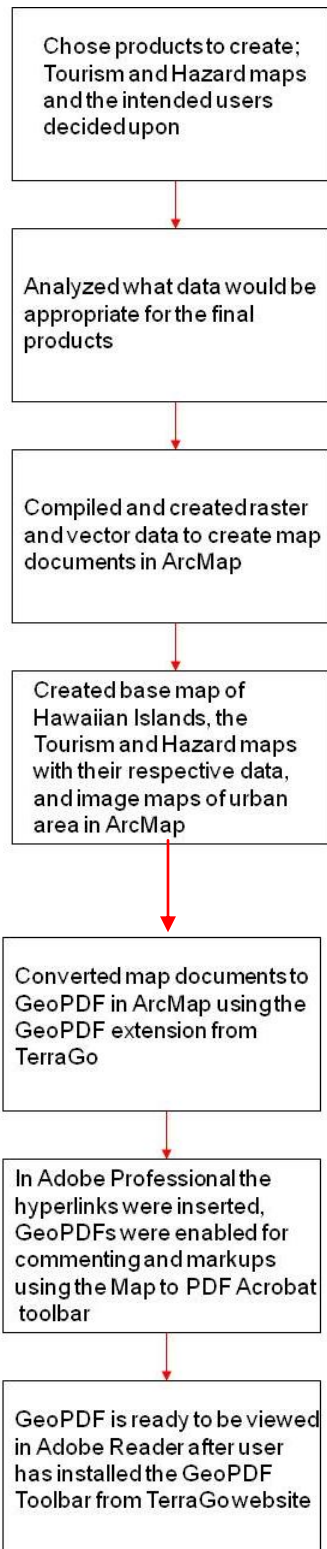


Figure 3: GeoPDF Construction Process

and one of Kona. They contained the same data as the tourism GeoPDF, but were created to display the city areas at a larger scale because of the abundance of data that was displayed for those areas. The appearance was too cluttered on the smaller scale maps.

3.3.1 Data Compilation

Various types of raster and vector data were obtained from multiple sources such as the Hawaii Statewide GIS program website and the U.S. Department of Agriculture as identified above. If the data in the shapefile or geodatabase format could not be found by searching the Internet, then alternative methods were used to produce the data. The Internet was then used to search for the addresses of attractions such as restaurants, nightclubs, golf courses, hotels, and cities. The attractions that were included in the tourism product were chosen because they are the main places that tourists visit when vacationing on the island. Google Earth was used as a reference to find where the establishments were located. The geographic coordinate was noted, and this coordinate was used in ArcMap to create shapefiles.

The shapefiles created were based on basic information that would be needed in times of a crisis and also information that is useful for tourists when visiting a new destination. The data used in the hazard map contained different types of data associated with natural hazards from volcanoes and tsunamis (Table 2). The hazard zones provided information such as what areas are at greatest risk of damage from lava flows. Residents might find it useful knowing the level of risk they are at from the lava that flows from

Table 2: Data Layers for GeoPDFs

1	Hazard Layers	Tourism Layers
2	Tsunami Heights	Attractions
3	Hospitals	Hotels
4	Airports	Golf Courses
5	Hawaii Cities	Restaurants
6	Volcanoes	Night Life
7	Emergency Shelters	Boating Facilities
8	Contours 500m	Body Surfing
9	Contours 100m	Hospitals
10	Major Roads	Airports
11	Volcano Boundaries	Hawaii Cities
12	Tsunami Evacuation Zone	Volcanoes
13	Hazard Zones 1-9	Major Roads
14	Landsat	Beaches
15	Hillshade	Parasailing
16		Landsat
17		Hillshade

Kilauea based on Hazard Zonation data. The evacuation shelter data are pertinent for people who might live in the path of lava flows or might be in danger of a tsunami. They need to know where they can go in case they need to evacuate their homes. Hospitals and major roads traveled to reach hospitals were included in case people sustained injuries. Hawaii is not excluded from natural disasters, and has been affected by tsunamis and hurricanes in the past; therefore knowing where evacuation shelters and hospitals are located could be very useful in emergency response. The tourism map contained several data layers such as hotels, attractions, beaches, restaurants, nightclubs, and golfing. These are all activities that people normally enjoy when on vacation. All of the information is provided in one place and is very accessible to the user.

3.3.2 Data Organization

The data that was either downloaded or created was assembled into their respective ArcGIS Map Documents and then converted to GeoPDF format using the TerraGo Publisher Suite (formerly known as Map2PDF). This must be installed on the computer to create the GeoPDF. The software requires a license and must be purchased from TerraGo Technologies. The cost of Publisher Suite Bundle is approximately five thousand dollars. The Publisher Suite Software Package gives the analyst the ability to use all of the TerraGo tools in ArcMap and Adobe Professional; these tools create a GeoMark enabled GeoPDF that a user can view in Adobe Reader. A GeoMark allows the user to add comments to points, rectangles, lines, polylines, polygons, and place stamps that represent incidents, infrastructure, natural events, and operations added to the GeoRegistered PDF files. The software included in this bundle is for ArcMap and Adobe Professional. With the Publisher Suite Bundle the TerraGo toolbar for ArcMap gives the analyst the power to convert map documents to GeoPDFs. Publisher Suite also gives the analyst the TerraGo tools needed for Adobe Professional such as MapAssembler and the GeoMark enable tool, which gives the analyst the ability to GeoMark enable the GeoPDF. Users will then be able to view a GeoPDF with Adobe Reader and have the capability of creating GeoMarks.

ArcMap was used to create original GIS products with the shapefiles, Digital Elevation Models (DEMs), and imagery coming from multiple sources. The focus of the research was to create user friendly GeoPDF products that were aimed at providing hazard, emergency response, and tourist information to residents and visitors of the island. The base map is set at a 1:850,000 scale that included hyperlinks to a hazard map

and a tourism map which are both at a 1:250,000 scale. The scale was chosen because there are several data layers and labels contained in the map, and if the map was at a smaller scale, the information would be difficult to see and appear cluttered. There were also hyperlinks from those products to orthoimagery. The hazard map contained symbology that was very easy to distinguish. The symbols chosen were based on common symbols that people are familiar with. For example, using the capital H with the blue background is a universal symbol for hospital, or using an airplane to depict the airport. The colors chosen for the hazard zones were picked because of the contrast among them, and they are easily distinguishable. The tourism map had common symbols for restaurants, such as a knife and fork, or a person swimming was used to represent beaches. Also all of the symbols used on the map are depicted within the legend, so the user knows what the symbols represent. Maps generally are displayed with raster data as the bottom layer and vector layers arranged on top. Both the hazard map and the tourism map included a hillshade with Landsat satellite image placed on top with a transparency so the terrain can be visualized. The intent of the chosen symbology was to make the products simple and easy to use and understand for someone who may be unfamiliar with map symbology. All of the features on the map are also labeled to provide the maximum amount of information possible without making the map appear too cluttered.

The GeoPDF extension in ArcMap from TerraGo has the ability to embed layers, embed attributes, define a coordinate system, embed hyperlinks, and set visible scale ranges. An important option when exporting an ArcGIS Map Document to a GeoPDF is to enable the layers box so the layers will be embedded and appear in the GeoPDF file as they appear in the table of contents in ArcMap. This allows users to turn on and off

layers in Adobe Reader. Image and vector options are available such as resolution and compression methods. Attribute options allow GIS analysts to check which fields in the attribute table will be able to be viewed in Adobe Reader. The hyperlinks tab gives the analyst control over which hyperlinks they want retained in the GeoPDF document. Coordinate systems can also be defined based upon what area the product is focused on. There are several options available, but it is the analyst's decision as to which options will provide the best product. When exporting to a GeoPDF, it is important the map document is in layout view because it respects page size, map scale, and preserves presentation aspects. This means that when the map is printed, it will print everything exactly how it is saved. For example, if the map created were 20 inches in width and 30 inches in length with a scale of 1:5000, that will be the dimensions and scale of the final product when printed.

The products developed within ArcMap for this study contained embedded layers, annotations which can be turned on and off within Adobe Reader and embedded fonts, which preserves the symbology when viewed in another program. With the TerraGo toolbar for ArcMap, the settings options were used to export the document at 250 dots per inch (DPI), and the quality of the image was set at best. Documents exported at DPIs greater than 250 can cause ArcMap to crash.

After exporting the document to a GeoPDF, the TerraGo Publisher Suite (formerly known as Map2PDF) for Adobe Professional was used to enable the GeoMark functions for the document. When the newly created GeoPDF was opened in Adobe Professional, geospatial coordinates were displayed in the lower right hand corner of the document as the mouse was scrolled around. The important processes that must be

completed in Professional were enabling for commenting in Adobe and GeoMark enabling, so the commenting and analysis functions can be used in Adobe Reader. This is where users would also create hyperlinks to web pages or images. If the first two steps were not enabled, then people viewing the document using Adobe Reader would not be able to use the GeoMark tools or to write comments in the document, so these steps were very critical. Enabling the document is a simple step and is done by clicking on the GeoMark enable icon. After the document is enabled, it is ready to be viewed in Adobe Reader. These products give users a different perspective of common software such as Adobe Reader in that the user has control over what data they want to view on the map by turning on and off layers, obtaining geospatial grid coordinates, and providing an abundance of information for the study area.

The hazard and tourism GeoPDFs contained hyperlinks to relative information and pictures. These products could minimize the amount of time one would have to search the Internet to find this information. It also provided the user the convenience of allowing markups to be created or comments written within the document, such as opinions of restaurants or beaches. These can be saved and shared with other people. The GeoMark can also be exported as shapefiles, but with the TerraGo Desktop toolbar (formerly known as GeoPDF toolbar) for Adobe Reader; the user would be able to create geospatial files from non-GIS software. These files can be opened in programs like Google Earth also. GeoPDFs can be created to target a specific audience and the data can be prepackaged, if it is known what the user expects or needs from the product. For example, if products need to be created to assist in disaster relief for an area that was destroyed in a hurricane, the prepackaged data could be saved on a laptop or external

hard drive, and the appropriate GeoPDF products could be created without the use of the Internet.

CHAPTER 4

ANALYSIS RESULTS AND DISCUSSION

4.1 Operations or Use of GeoPDF

For people to be able to view the GeoPDF products, Adobe Reader needs to be installed on the computer. If it is not installed, the latest version of Adobe Reader can be downloaded at this website (www.adobe.com/products/reader/). Adobe Reader version 9.x provides two native geospatial support tools, Object Data Tool and Geospatial Location Tool that work with geospatially enabled PDFs. These features add more dimension to the GeoPDF by allowing the user to obtain additional attribute or geo-referenced information about the layers. A built-in Layer Manager on the left side of the document allows the users to toggle different spatial layers on or off to change the displayed map (Figure 4). A layer that is visible has an eyeball next to it. When the plus sign is clicked, all of the layers are expanded and visible, and when a layer is turned off, its labels are no longer visible on the map. The Object Data Tool allows the user to click on a symbol on the map and display its attribute information on the left side of the document (Figure 5). The order of the layers in GeoPDF and the attributes to be displayed were pre-determined and assembled by the analysts in ArcMap.

The TerraGo Desktop (formerly known as GeoPDF toolbar) is free plug-in software used in Adobe Reader that allows the user to obtain coordinates on a map, measure distances and angles, track positions using a GPS device, and display coordinates in multiple projections, regardless of the original coordinate system of the data. This plug-in software can be downloaded from TerraGo's website

(<http://www.terragotech.com/solutions/geopdftoolbar.php>). The latest version is 4.1.2 and is compatible with Adobe Reader versions 7.x, 8.x, and 9.x as of January 2009 (TerraGo Technologies 2009).



Figure 4: Table of Contents for Hazard Zonation GeoPDF

The TerraGo Publisher Suite (formerly known as Map2PDF) enables the analysts to assemble the geospatial information into GeoPDFs, then enable GeoMark functionality in Acrobat Professional, so the final users can create spatial features as marking or comments on the document in Adobe Reader. Without GeoMark enabling and enabling for commenting in Reader, which are two separated steps, the GeoPDF files can only use

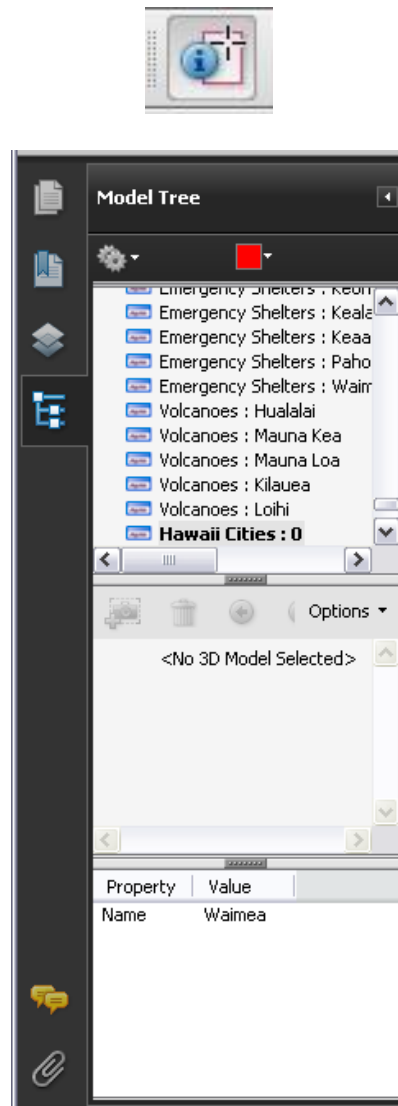


Figure 5: Object Data Tool and Attribute Table

the native functions provided by Adobe Reader. However, once the GeoPDFs have been GeoMark enabled and enabled for commenting in Adobe using the TerraGo Publisher Suite and Acrobat Professional, the general users can utilize full functionality of the TerraGo Desktop, which are GeoPDF Toolbar and GeoMark Toolbar.

The GeoPDF Toolbar (Figure 6) functions include the GeoTool, the GeoLocator, the GeoMeasure, the GeoTrack, and the GeoInfo tool. The GeoTool locks and unlocks coordinates, has the ability to GoogleMap the selected coordinates, and can launch other GeoPDF tools. The Google Map feature launches an internet browser and displays the selected coordinate in Google Earth. The GeoLocator shows and finds coordinates and provides the option to change the coordinate system display. This is an important feature because not everyone uses the same coordinate system. The GeoMeasure can measure length and area and also calculate azimuth and magnetic bearing. The GeoTrack tool displays the current position of an attached GPS unit. The GeoInfo tool can import data as annotations, delete data, or export data. With the GeoInfo tool on the toolbar, several types of data can be imported into the GeoPDF such as *.csv, *.gpx, *.kml, *.kmz, and *.shp files.



Figure 6: GeoPDF Toolbar

The GeoMark Toolbar (Figure 7) includes Add GeoText, Add GeoRectangle, Add GeoLine, Add GeoPolyline, Add GeoPolygon, Add GeoStamp, and Export all GeoMarks. These are the different features that can be created in the document by the end user if the GeoPDF is GeoMark enabled. The Add GeoText tool allows the users to add their own sticky notes in the documents, which can be used to communicate opinions or exchange experience between them. The draw tools create points (GeoStamp), lines (GeoLine, GeoPolyline), and polygons (GeoRectangle, GeoPolygon) with geospatial reference, which can be used to define boundaries or points of interest to scientists or tourists. The GeoStamp tool also allows users to insert symbols with notations that represent incidents such as terrorism or natural events. Only features created by the GeoMark tools can be saved and exported as *.kml files or *.shp files, and then imported into programs such as Google Earth and ESRI ArcGIS. Users do not have the capability to export layers that are already in the GeoPDF, only those created with the GeoMark

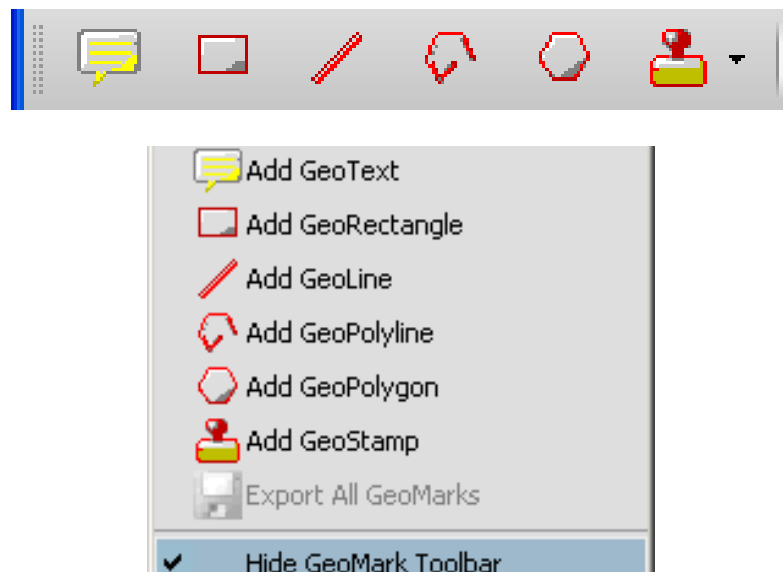


Figure 7: GeoMark Toolbar

tools. With this additional functionality, geospatial data can now be created from a software program that was traditionally non-GIS software.

4.2 Overall Structure of Products

The final product consisted of five GeoPDFs. (Figure 8) The first product was an orientation GeoPDF of the Hawaiian Islands (Figure 9) set at a 1:850,000 scale with hyperlinks to a tourism GeoPDF (Figure 10) and a hazard GeoPDF (Figure 11) for the Big Island of Hawaii at a 1:250,000 scale. The orientation GeoPDF was used to display all of the Hawaiian Islands with some of the islands' major cities depicted. Both the tourism and hazard products contained data such as cities, airports, hospitals, and transportation networks.

The tourism GeoPDF contained data pertaining to hotels, restaurants, beaches, golf courses and shopping. The tourism GeoPDF contained two hyperlinks to two image map GeoPDFs. One was of the city of Kona and the other of Hilo. These products contained the same data as the tourism GeoPDF, but are at a much larger scale so the data does not appear too cluttered. The hazard GeoPDF contained data such as hazard zones, which was based on past lava coverage, historical tsunami data, and evacuation shelters. The hazard GeoPDF also included a document with detailed information on each of the hazard zones displayed on the map. These products also contained hyperlinks to imagery and web pages that would provide additional information to tourists and residents of the island.

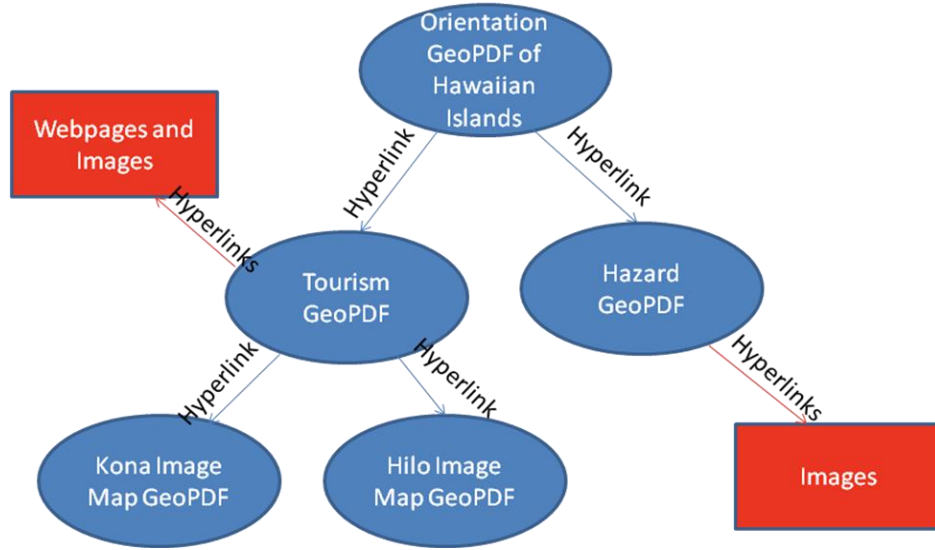


Figure 8: Overall Structure of Products

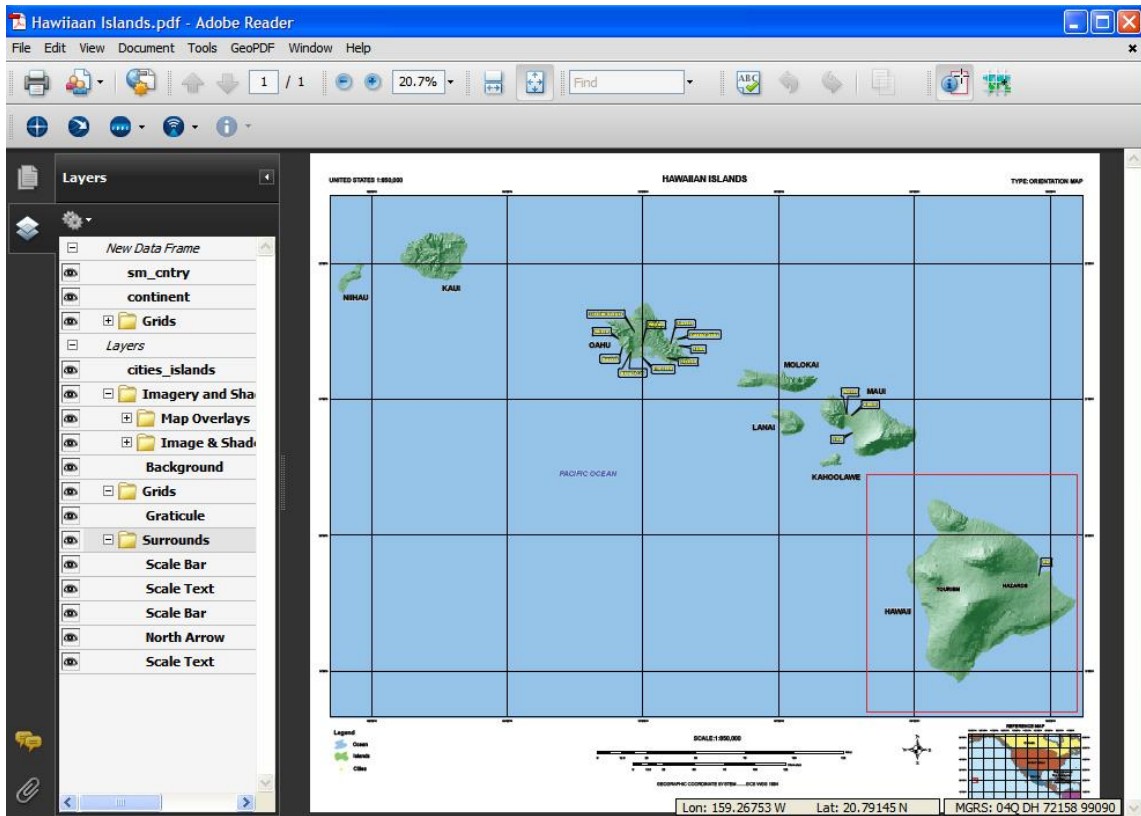


Figure 9: Orientation GeoPDF of the Hawaiian Islands

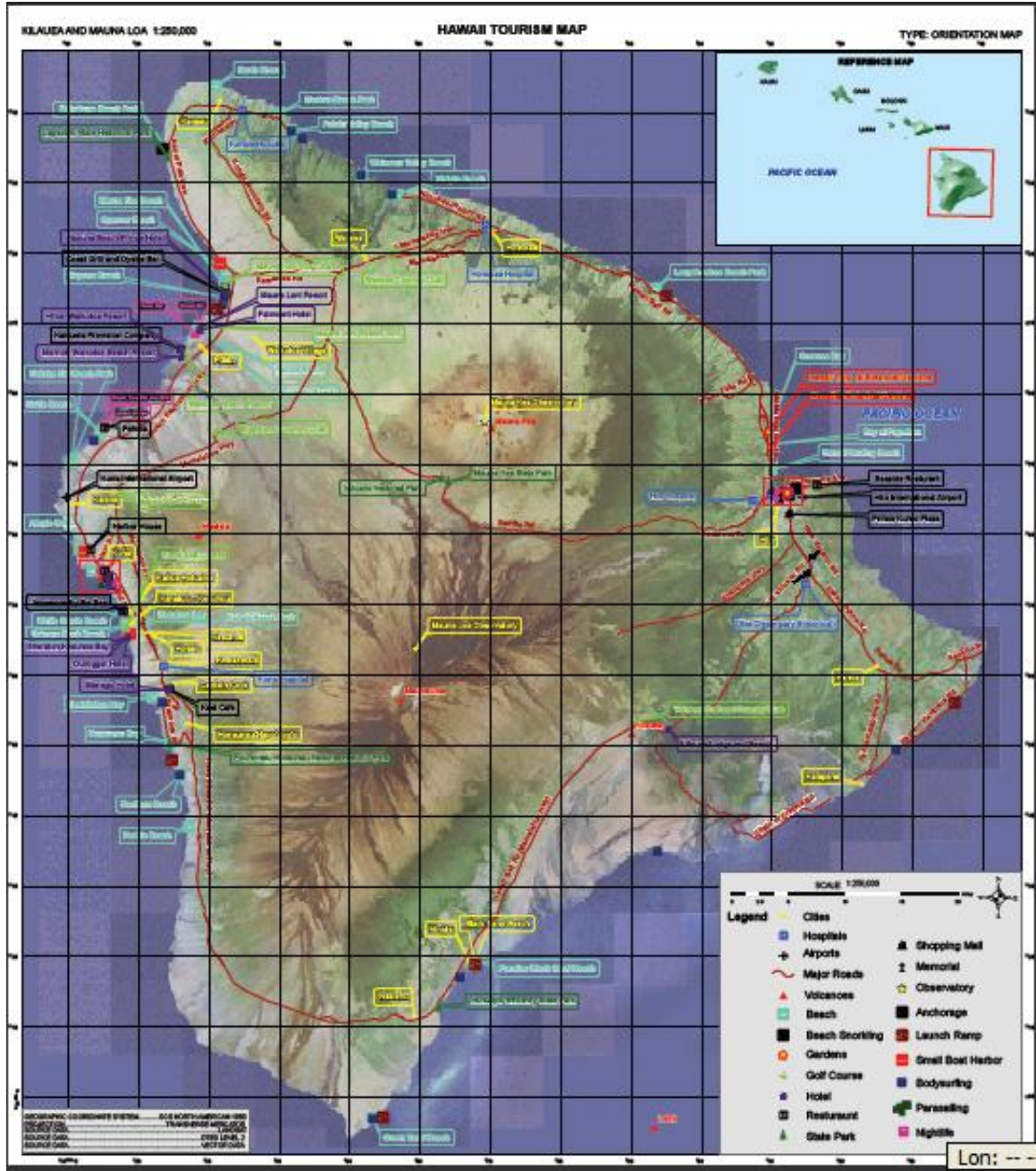


Figure 10: Hawaii Tourism GeoPDF

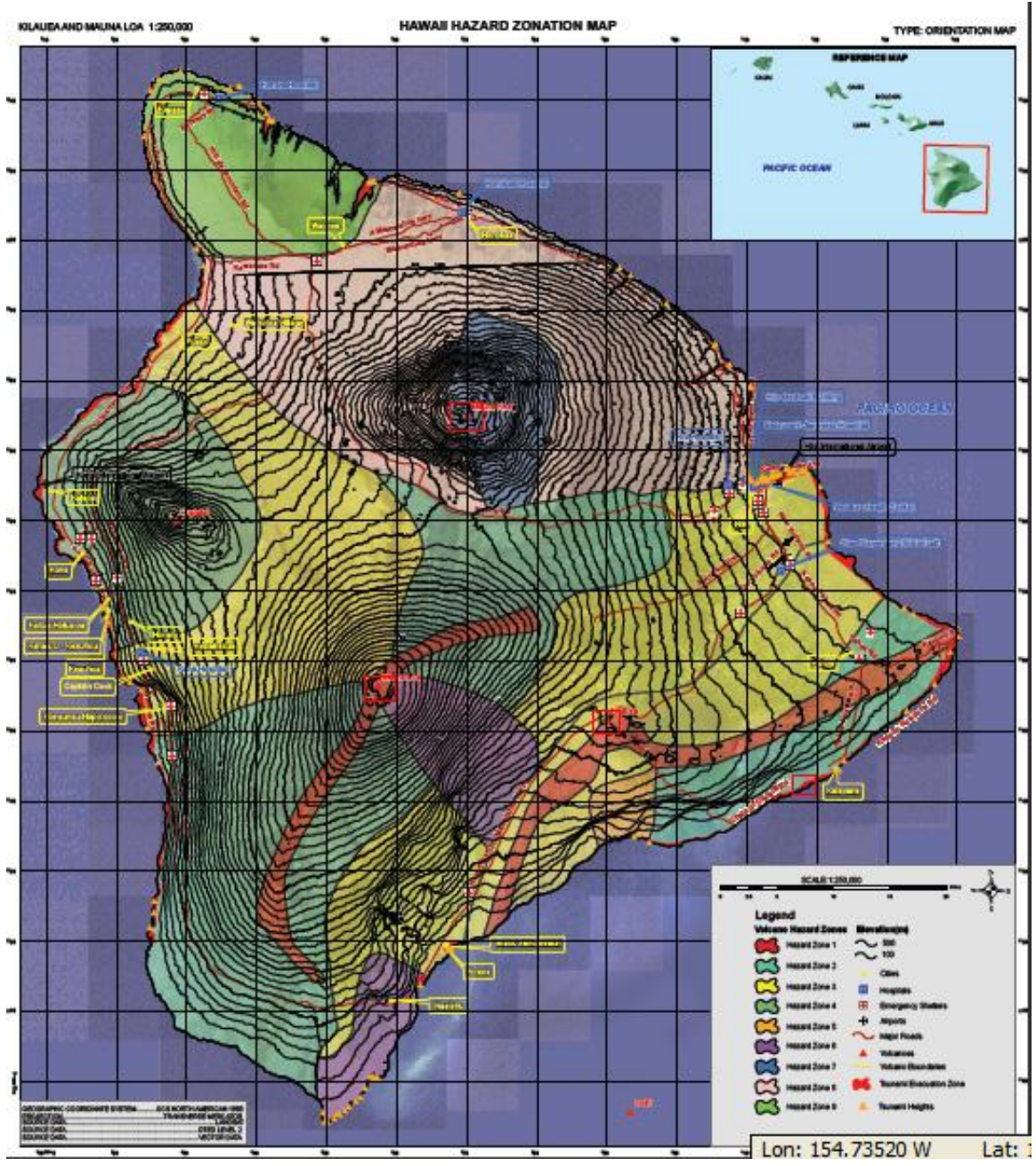


Figure 11: Hawaii Hazard Zonation GeoPDF

4.3 Hazard GeoPDF

The hazard GeoPDF for the Big Island illustrated lava flow hazard zones based on past volcanic data from the Mauna Loa and Kilauea volcanoes. This data took into account the location of past eruptive events, past lava coverage, and topography. These nine zones displayed the areas at greatest risk with Zone 1 (Figure 12) being the highest and Zone 9 (Figure 13) being the lowest based on Hazard Zones maps from Hawaiian Volcano Observatory (HVO). Areas within Zone 1 are at greatest risk for possible lava damage. This is where fissures have been continually active. The boundaries for Zone 1 are defined by eruptive fissures, cinder cones, and pit craters. Zone 9 is defined by a volcano that last erupted over 60,000 years ago. Past lava flows were responsible for destroying several homes and roads. This type of data would be very useful for insurance agencies, home owners, and any potential home building contractors.

This hazard GeoPDF also provided important information such as the location of evacuation shelters and hospitals and the attributes located below the table of contents, such as past tsunami heights (Figure 14). Hyperlinks that were created in Adobe Professional are linked to either websites or to close-up imagery shots (Figure 15) at a larger scale in Adobe Reader. A document that was created by the Hawaii Volcanoes National Observatory was inserted into the GeoPDF that provides a description of the significance of each of the nine hazard zones in the map. The Add GeoStamp (Figure 16) tool allows the field officials to easily insert the markup of incidents into the GeoPDF, which would be ideal for emergency preparedness and response.

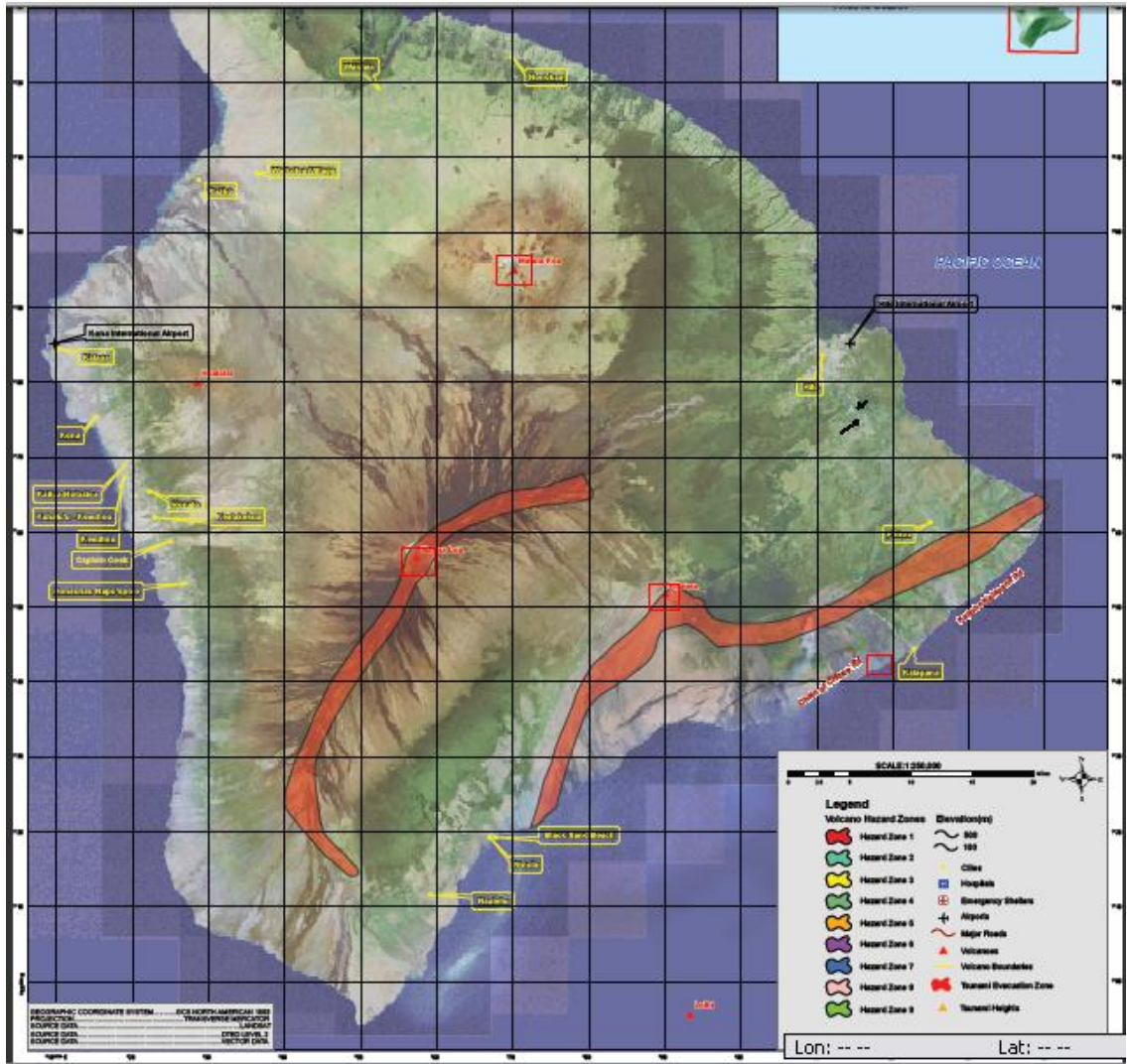


Figure 12: Hazard Zone 1

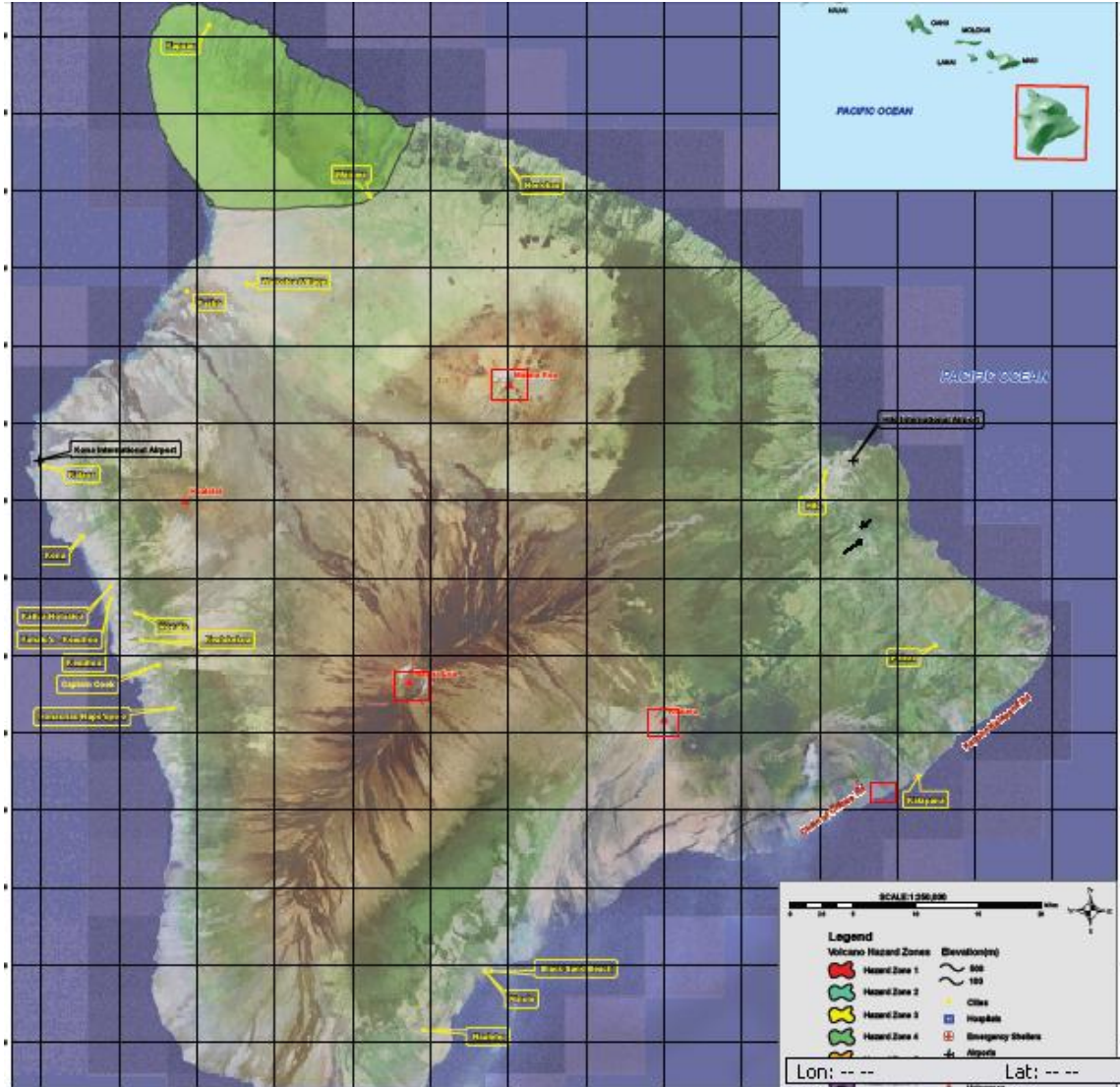


Figure 13: Hazard Zone 9

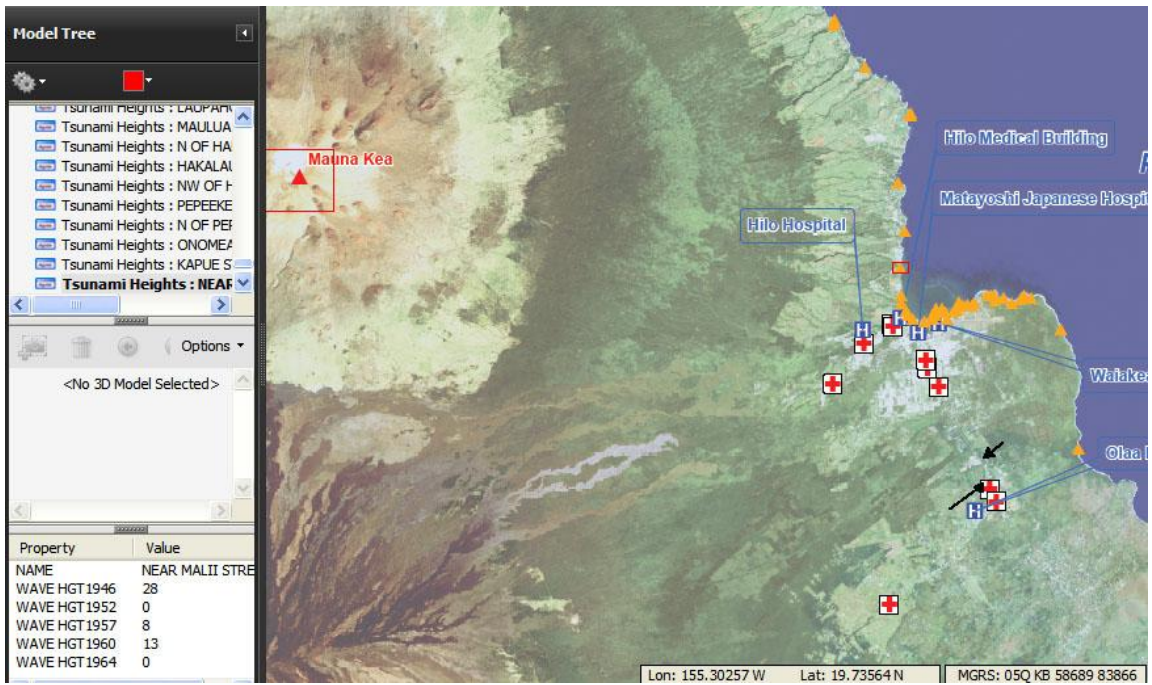


Figure 14: Emergency Response Information in Hazard Maps

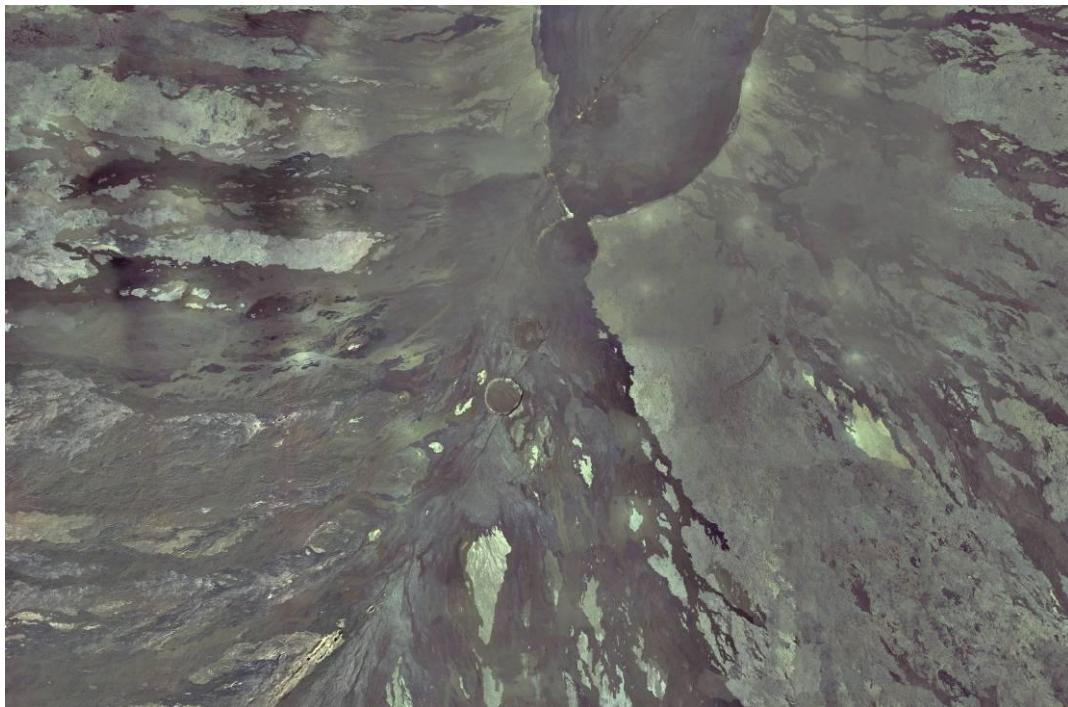


Figure 15: Close-up Image of Mauna Loa



Figure 16: Add GeoStamp Tool for Natural Disasters

4.4 Tourism GeoPDF

The tourism map showed the locations and hyperlinks of the Big Island's best resorts and restaurants. It also included locations to several beaches around the island and gave tourists ideas to some popular tourist attractions on the island such as scuba diving and visiting botanical gardens and observatories. This map also provided additional information on some National Parks, such as the Hawaii Volcano National Park with a link to the park's website that includes real time data about current lava flow. Many visitors of the island might also enjoy playing golf (Figure 17) at one of the several golf courses the island has to offer. Image shots of all of the golf courses were provided. Hyperlinks were provided to all of the major attractions, which could significantly reduce the amount of search time expended by tourists. There were also hyperlinks for every hotel (Figure 18) which included availability and room rates. Image maps were also hyperlinked within this map because the two major cities Kona (Figure 19) and Hilo (Figure 20) have several restaurants and hotels located in the same area. Users of this product could personalize their own map using the Add GeoText tool to update the product with notes about their favorite restaurant or beach they had experienced (Figure 21). This map would be a great way for tourists to exchange information and communicate their ideas and opinions of hotels, restaurants, and activities to other tourists who are looking for places to stay and eat.

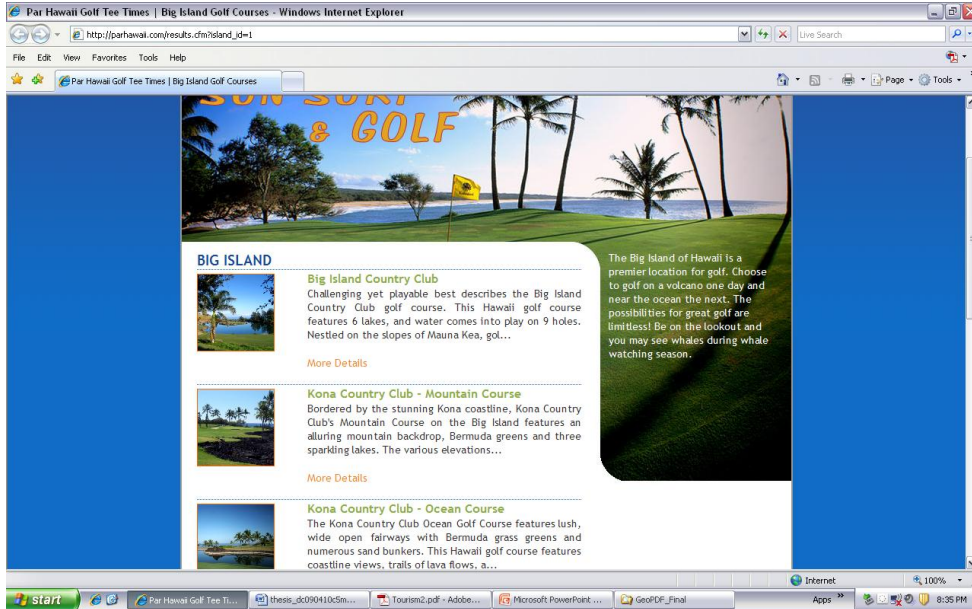


Figure 17: Big Island's Golf Course Website from Tourism GeoPDF Hyperlink

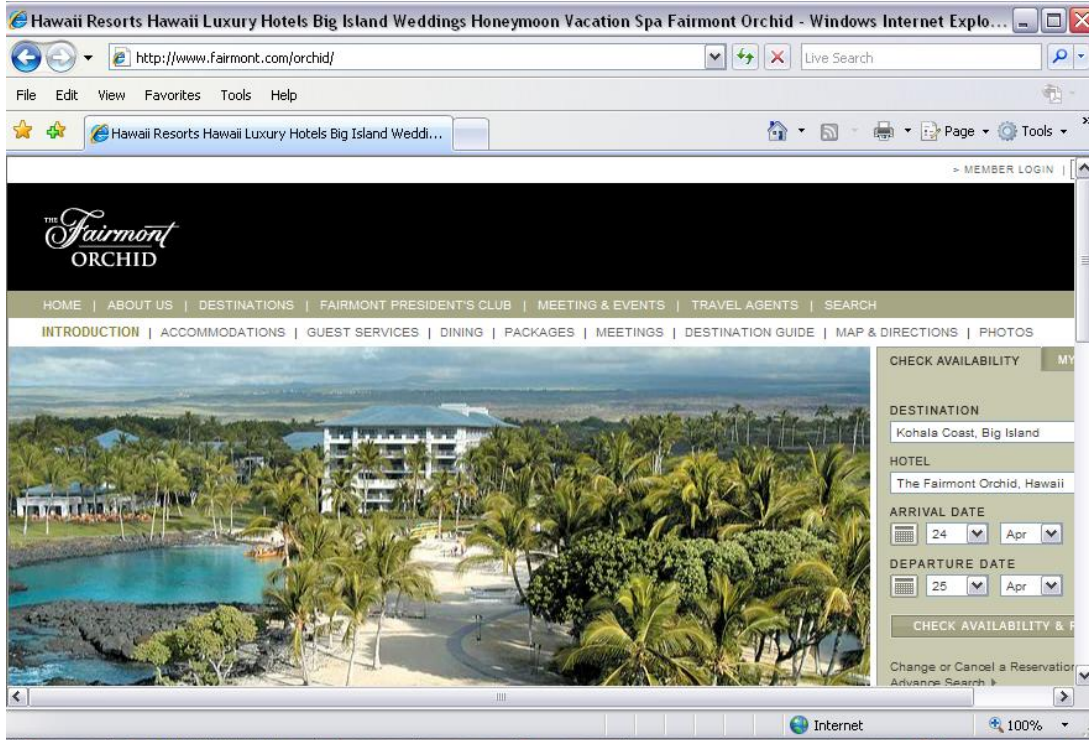


Figure 18: Fairmont Hotel Website from Tourism GeoPDF Hyperlink

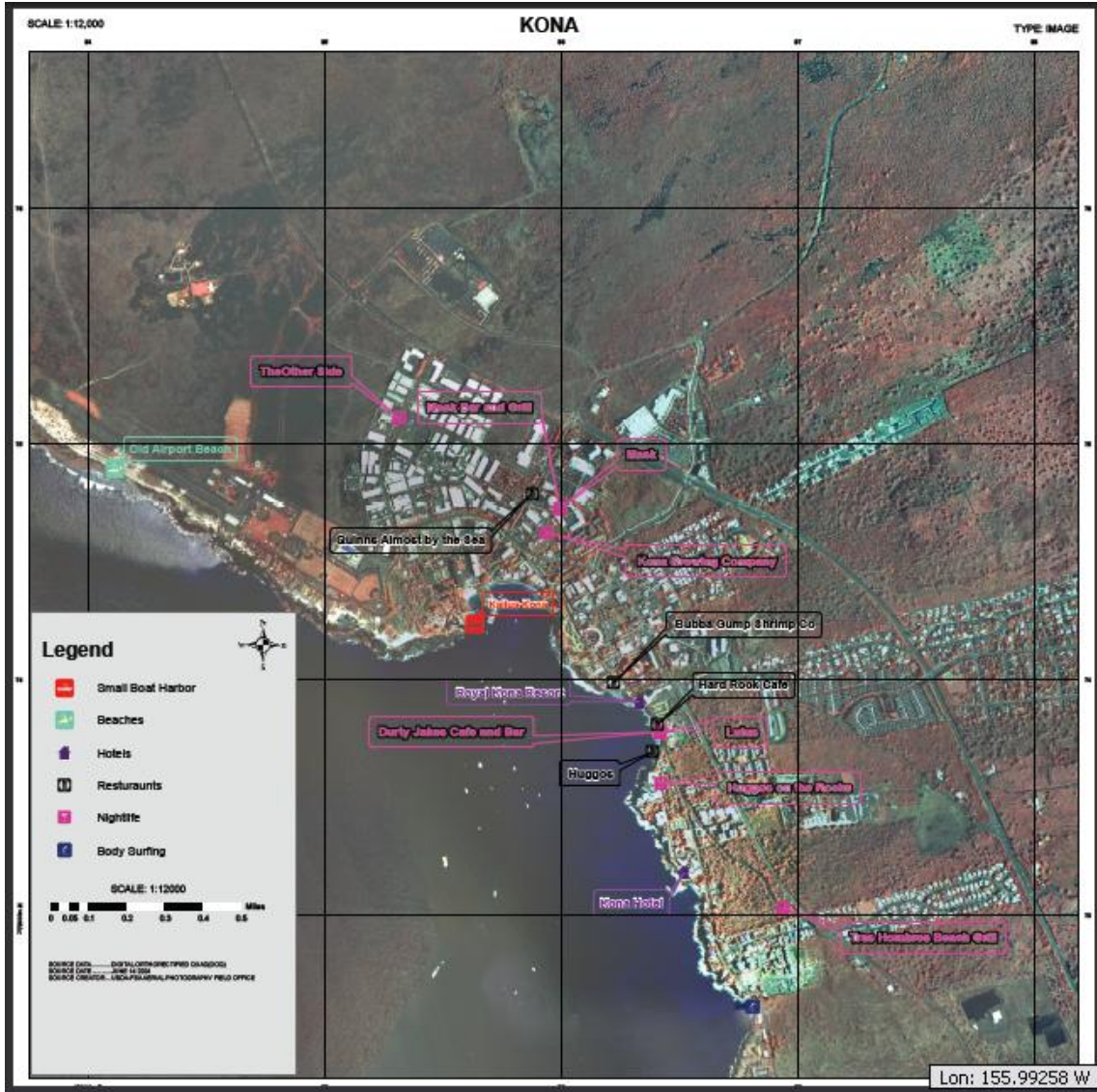


Figure 19: GeoPDF Image Map of Kona

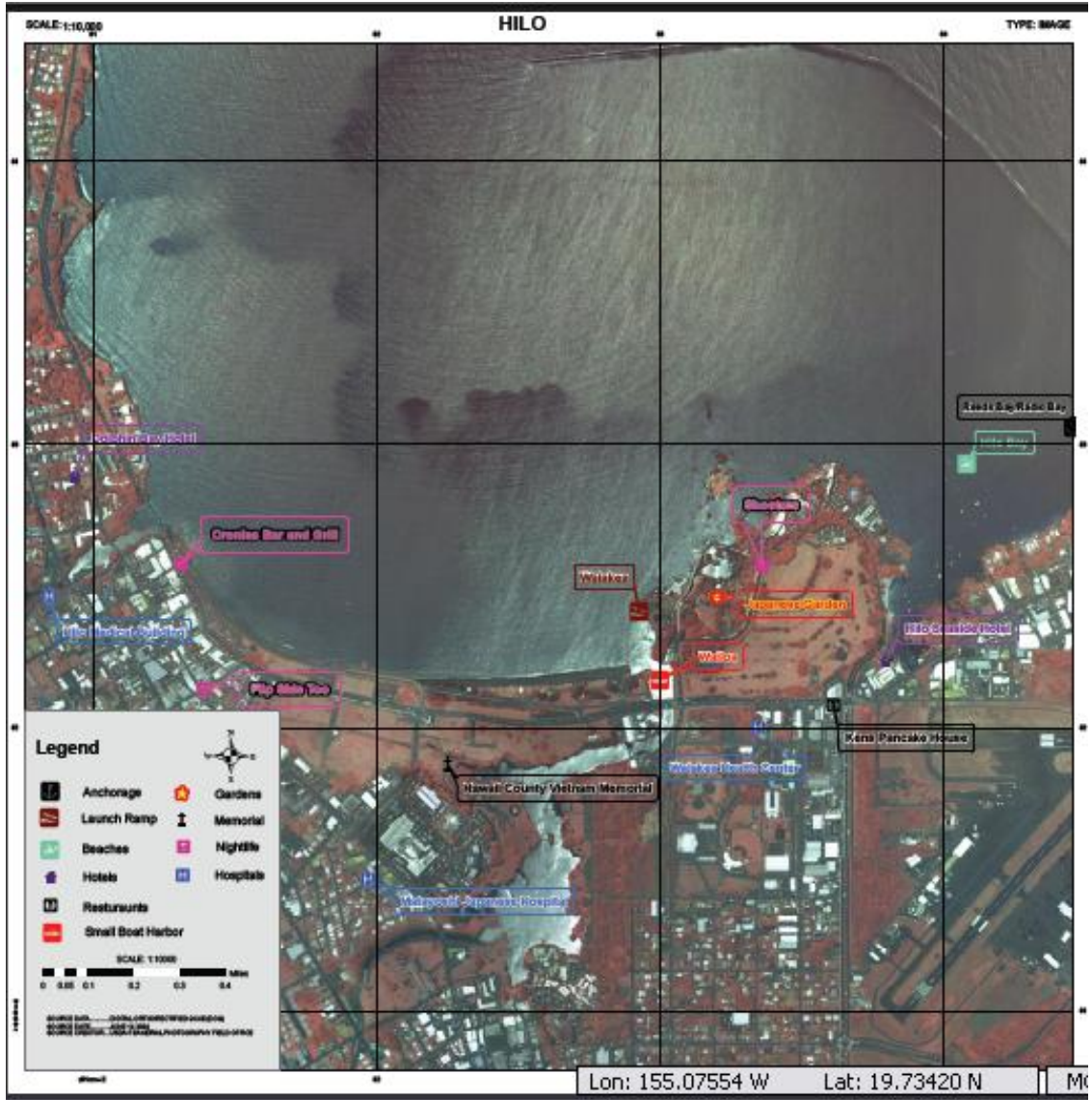


Figure 20: GeoPDF Image Map of Hilo

4.5 Discussion

These products were simple to use because of the easily recognizable symbology and an abundance of hyperlinks available by clicking on the symbols. Everything was labeled so there was no second guessing as to what represents what, and labels were the same colors as the symbols they represent. Plenty of information was available by the single click of a button. The GUIs (graphic user interfaces) available from the TerraGo Desktop were accessible by one click, and users could make several changes or updates to their products. The layers were labeled in the table of contents so the users could turn off the layers they didn't want to view without going through all layers to find the correct one. The user would most likely already have some confidence when using this product because it was viewed in familiar software.

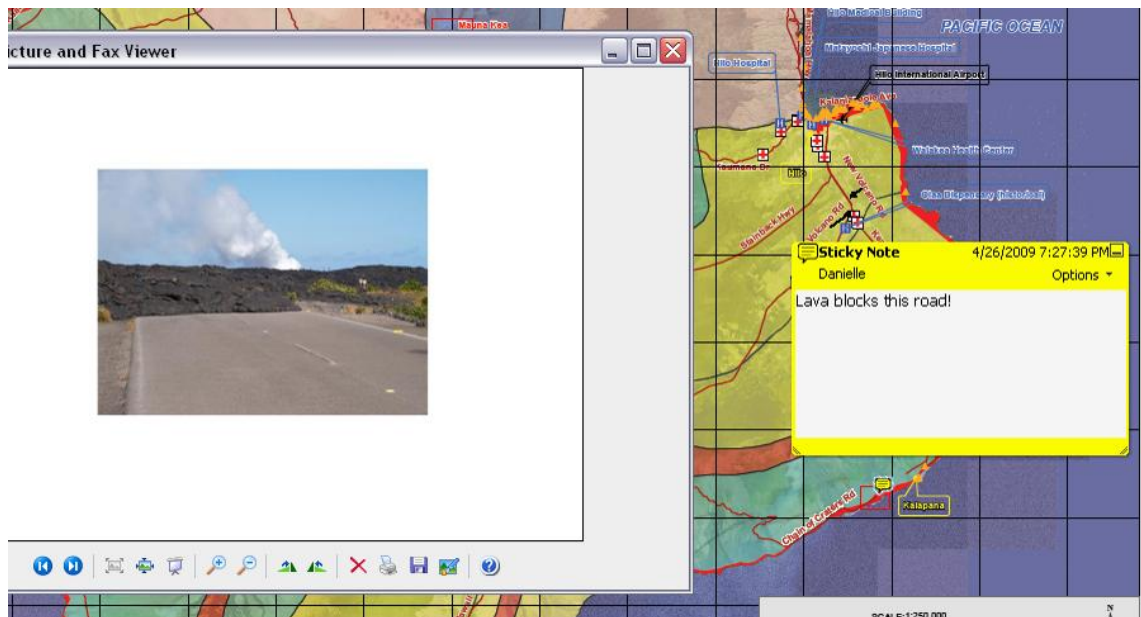


Figure 21: Add GeoText Tool for Exchanging Opinions

There were some issues encountered with using these products. One of the issues was the Internet connection. Internet access is required to download the TerraGo toolbar. The Internet is also necessary if the GeoPDF is hosted on a website, or if there are hyperlinks within the GeoPDF that the user wants to activate. There is a solution to this issue and that is putting the GeoPDF on a disk or hard drive. Without Internet access, the appropriate tools and software would not be available for download. Users would also have to familiarize themselves with the new GeoPDF tools, but the help menu will assist with any questions one might have. Another problem might be dealing with a slow refresh rate of the GeoPDF. GeoPDFs with a few layers had a much smaller file size compared to GeoPDFs with several layers. The larger the file size the longer it took for all of the layers to display. Some raster data such as Landsat imagery could cause the GeoPDF to be several megabytes in size and result in slow refresh speed, but another helpful tool to provide large scale imagery was the Google Map-It tool. By clicking on the GeoTool icon, the Google Map-It option was given. If an Internet connection was available, the users could click anywhere on the map and an image of the area would be displayed in a new viewer.

End users of these products would probably be the biggest assets keeping these types of maps updated. They could place a GeoMark or a GeoStamp with TerraGo Desktop in the GeoPDF map to add a new restaurant with reviews of the menu and food. The Internet connection should most likely not be an issue for the tourists, because many hotels offer Internet in every room or amenities such as Internet cafes with printers to print off their personalized maps. These personalized maps contained the data the user

decided to display, the data that is most beneficial to them, and any notes or markups that they added to the product.

From the analyst perspective, it was imperative that all of the appropriate software and extensions were installed so that all of the final products had the appropriate data, and hyperlinks. It was also important to make sure that all of the links worked correctly when the document was hosted on a website. All of the documents needed to be checked to make sure they were GeoMark enabled and enabled for commenting in Adobe or the users of this product would not be able to create markups and comments. One challenge encountered was the size of the documents. Because the goal is to deliver a product that would be easy to see when viewed at 100%, the final products were created at a larger scale. Creating the products at this size made the documents several megabytes in size and could take a while for a user to download. In the future this product could be created at a smaller scale. Adding raster data using the TerraGo tools within Adobe Professional instead of ArcMap will reduce the file size.

CHAPTER 5

CONCLUSION

The objective of this thesis was to provide a personalized geospatial product to residents of Hawaii, tourists, geologists, and emergency response teams. The objective was met by creating specialized GeoPDFs where the user had control of what layers they wanted to see displayed. The data provided in the final products were specific to the targeted audience, but users had the capability to customize the products based on their needs. The products were viewed in a frequently used software program, Adobe Reader, which is available for free download. The TerraGo Desktop gives the users even greater control of what is displayed on their map such as reviews of restaurants or the nearest evacuation shelter in times of an emergency. These products provided a quick reference to some essential information with the ability to obtain geographic coordinates.

This GeoPDF map book contained five different maps with many data layers to choose from, such as transportation routes, hospitals, cities, hazard zones, and beaches. Users will be able to customize their own product. All of the layers contained attribute data which provided additional information about individual objects in the layer. When the object data tool is used, the user can click on an individual object and any information that is available will be displayed. For example, if the user clicked on a tsunami height point, they would be able to obtain the height of the tsunami at that location for a given year. The hyperlinks provided additional information by linking directly to hotel websites. Other links thought to be useful were also made available in the GeoPDFs. Internet would be required to use all of the options that are available within the GeoPDF.

GeoPDFs have advantages over other GIS services and products due to the fact that the software is free, but users still have limited GIS functionality. Table 4 shows the comparison of different products and the advantages each has to offer. For example, ArcMap is interactive for the analyst creating the product but not for someone who does not have the appropriate software. GeoPDFs are user friendly and require limited GIS experience (maybe just the experience with Google Earth or Map Quest). Google Earth is considered to be fully interactive, but it does require constant Internet access. GeoPDFs have some limitations, but overall require the least amount of skill and resource to use.

5.1 Limitations of the Research

One of the difficulties associated with this research was finding suitable data and deciding what data should be in the product. There was much data available, but it did not include everything that was needed. Data had to be created to fulfill the requirements of the products. Because of the distance of Hawaii from my current location, no onsite analysis was completed; the Internet was used to obtain all information. Making sure there was not too much data in one product was important because too much data for a small area might be excessive and could be overwhelming. A decision was made as to what information was most relative to fit the theme of the product. The organization of the data layers was something that could have been improved upon, such as creating groups for the layers that are similar such as the nine different hazard layers. The reference map should have been moved to the bottom of the table of contents, just to maintain better structure among the data. This would have been completed in ArcMap.

Table 3: Comparison of Products

	Experience Level	Cost	Internet Required	Interactive
GeoPDF	Non-GIS Specialist	Free	No	Limited to Data Set Provided
Hard Copy Maps	GIS Specialist	\$	No	No
ArcMap Software	GIS Specialist	\$2,500.00	No	Yes for Analyst
Google Earth	Moderate	Free	Yes	Yes

The other issue was deciding if this product was going to be easy for people to understand when using the GeoMark and GeoPDF tools and to understand the full capability of the product. Will people feel comfortable with the product because it is viewed in Adobe Reader which most people already have experience using? Internet access would initially be needed to have access to the products if they were hosted on a website. There is a greater amount of data available with access to the Internet, but these documents could still be printed out in PDF format so they could be referenced in the field or when travelling. The limited amount of available research papers related to GeoPDFs was also a problem in this project. GeoPDFs are gaining recognition, but there was minimal reference material available making it difficult to conduct a formal literature review.

There were limitations encountered when creating the GeoPDFs. The Internet and GIS software helped to alleviate these problems by aiding in creating new data. First, searching the Internet for data that was needed was very time-consuming, and not all could be easily imported into GIS software. More research to find addresses of the locations and geographic coordinates for places such as restaurants and night clubs had to be conducted by using Google Earth as a reference. After the coordinates were obtained, feature layers were created from those coordinates in ArcMap.

Another limitation was having all the appropriate TerraGo software and licenses, and making sure that everything was working properly. ArcGIS 9.3 provides the ability to export its map document into GeoPDFs, but these documents could only use the native Adobe Reader geospatial functions (Object Data Tool and Geospatial Location Tool). The license that was required to create fully functional GeoPDFs was the TerraGo Publisher Suite (formerly known as Map2PDF); without it, the exported GeoPDFs couldn't be enabled for commenting and GeoMark in Adobe Professional. This forces the analyst to purchase Publisher Suite to give the end users full capability of the TerraGo tools in Adobe Reader.

A well designed process to assemble all geospatial information for GeoPDFs is critical. A GeoPDF is able to be brought back into ArcGIS, but it can only be viewed not be manipulated any further. The revision had to be made in the original map document. If mistakes were found in the GeoPDF, the author would have to fix them back in the ArcGIS map document, export the map again, and reset all the links in Acrobat Professional. This created extra work that was not necessary, and alternative ways should have been examined to address the issue. These problems could be minimized with the quality control process before the map documents were exported into GeoPDFs.

One other issue of this project is that the file size of the final GeoPDF product was extremely large, approximately 250 megabytes, which made it difficult to transfer or download between platforms. Two main reasons were because of the scale the GeoPDFs were created at and also the amount of data that was in the GeoPDFs. Future projects could be created at a much smaller scale to reduce the file size, making it easier for users to download the products. Another alternative way to reduce the file size of the GeoPDF

is to assemble the layers through the TerraGo software in Adobe Professional instead of exporting the assembled map document directly from ArcMap. To Assemble through Adobe Professional the layers must be in the GeoPDF format. As an example, a map document was created in ArcMap set at a 1:15,000 scale. It contained ADRG data that was in an Imagine file format. When this map document was exported to a GeoPDF from ArcMap using the TerraGo tools, the file size was thirty-nine megabytes. To significantly reduce the file size of the GeoPDF, the map could be assembled using the MapAssembler tool in Adobe Professional.

The first step in reducing the file size was to export the map document as a GeoPDF in ArcMap without the ADRG layer. The ADRG layer is not needed in ArcMap to assemble it in Adobe Professional. The size of the exported GeoPDF was approximately four megabytes. The next step was to use Adobe Professional and open the GeoPDF that was created in the previous step. The analyst then had to click the MapAssembler icon and check the Add Active Layers to Map option. This would show the active layers in the MapAssembler window which would be just the base map GeoPDF at this point. The analyst would then have to click the browse button to add the ADRG that has been already been converted to a GeoPDF. The ADRG tile would have been moved to the top so the data gets assembled correctly. The Assemble button would then have been pressed, and then the product would have assembled. The file size of the GeoPDF created in Adobe Professional was fifteen megabytes, reducing the file size by twenty-four megabytes. Because smaller file sizes are easier to work with, it would be advantageous to assemble the map through Adobe Professional using the TerraGo tools.

5.2 Further Research

The contributions from this research included introducing new applications for GeoPDFs. The US Army and the USGS are two organizations that heavily use the TerraGo software to create mapbooks of several regions around the world. The products created by the U.S. Army are disseminated to soldiers deployed in the Middle East. This research established new groups that could take advantage of the GeoPDF such as tourists and scientists. These products could be made for any vacation spot or research site based on the availability of the data. Data that is collected in the field can also be imported into the GeoPDF and then printed to use as a reference for further research or data collection. What could possibly make the GeoPDF even more beneficial in the field is being able to install Adobe Reader on hand held devices like GPS units, I-Phones, and smartphones. It would be much more convenient to carry a small piece of handheld equipment into the field rather than a laptop computer. These products developed prove that GeoPDFs have several functions in society and there is definitely going to be an increase in the ways these products can be utilized.

Creating the products for the civilian sector proves that there are uses for the GeoPDF that are not military driven. Hazard maps are available for areas that experience landslides (Arora *et al.* 2004). GeoPDFs could be created for this type of natural disaster similar to the volcano hazard maps and used to track the damage caused by them and the rebuilding process. This type of product could be created for other types of natural disasters, such as hurricanes. From the research that has been conducted up to this point, no other hazard or tourism GeoPDFs have been found. This product could be easily assembled by any GIS professional who has access to the appropriate data. These types

of products could be created for any area that experiences hazards, such as those in Hawaii, or to provide tourists with interactive products that they can use to plan out their vacations. Other possible applications for the GeoPDF could include real estate, by displaying homes that are for sale, or those that have been foreclosed with links to pictures of the home and the real estate agencies information. Another application for the GeoPDF could be useful for homeowners who live in a flood zone. They could have an interactive product that could show what houses are in the flood zone to make the decision to purchase flood insurance. TerraGo has recently developed 3-D GeoPDFs and it would be interesting to find out how this could be applied in the field. The possibilities are endless and more uses will be discovered in the near future.

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