Developing, Maintaining, and Employing Crowd-sourced Geospatial Data in Support of Helicopter Landing Zone Surveys for Disaster Response Operations

by

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To the memory of the crew of VENGEANCE 01, lost while providing humanitarian relief to the people of Nepal, 12 May 2015

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List of Abbreviations

HA/DR	Humanitarian Assistance and Disaster Response
HLZ	Helicopter Landing Zone
MV-22	Medium lift (24-passenger) tiltrotor aircraft
NGO	Non-Governmental Organization

Abstract

Humanitarian Assistance and Disaster Response (HA/DR) Operations executed by the military forces of developed nations have proved to be powerful instruments of foreign policy. Militaries bring a significant vertical-lift logistical capability to HA/DR, in the form of traditional helicopters and modern tiltrotor aircraft. Military planners of HA/DR employ advanced geographic information systems (GIS) when planning Helicopter Landing Zones (HLZs). GIS continue to improve; however real-time ground-truth HLZ surveys would add a level of detail that may prove crucial to helicopter crews. Crowdsourcing efforts such as the Humanitarian OpenStreetMap (OSM) Team (HOT) have emerged as a highly effective means of gathering geospatial information about impacted regions in the immediate aftermath of a disaster.

This research endeavors to develop, test, and validate a series of straightforward, easily understood procedures for conducting a HLZ survey, which then can be made available to HOT volunteers. Military planners employ GIS and remote-sensing imagery to select potential HLZ sites. These sites are imported to OSM, where volunteers can obtain data as to their location. Volunteers can utilize the techniques developed in this research to conduct a ground-truth survey of the HLZ and provide the results back to the HOT. The HOT can verify these inputs and link them to the HLZ in OSM. This thesis describes the creation and validation of these processes in a study area focused on Hawaii County, Hawaii.

Chapter 1 Introduction

In the 21st century, Humanitarian Assistance and Disaster Response (HA/DR) Operations serve as one of the most effective expressions of foreign policy. Developed nations have regularly deployed military forces to support HA/DR, leveraging the logistics and security capabilities of these entities. This research effort is located at the nexus of volunteered geographic information (VGI) effectiveness and accuracy, VGI and formal GIS as applied to disaster response operations, and the science of helicopter landing zone (HLZ) selection and surveying. Included in this effort is developing a survey template for helicopter landing zone assessment for two towns of Hawaii County, Hawaii, to provide the Humanitarian OpenStreetMap (OSM) Team (HOT) a relevant and repeatable template for their Web- and Mobile-GIS applications. This line of research should yield an understanding as to what tools volunteer collectors of geospatial data could use to verify that pre-surveyed potential HLZs are still viable after a disaster. The research objective is to determine what sort of processes and application(s) could support helicopter operations during disaster recovery, in order to support a broader effort to design and develop these sorts of tools for disaster response planning applications worldwide. There has been extensive scholarly literature generated on each of the three areas detailed at the start of this paragraph; what is unique about this research is that it will show how to link these areas into a coherent geospatial workflow. Two desires motivate this research effort: to ensure that helicopter operations in support of HA/DR are as efficient and effective as possible, and to ensure that helicopter crews are not unnecessarily hazarded when executing HA/DR.

1.1. Study Area

This research focuses on the study area of the island of Hawaii County, Hawaii, commonly referred to as the Big Island. The Big Island is the easternmost island of the Hawaiian chain, and the largest of that archipelago. These islands reside in the Pacific Ocean approximately 3,200 kilometers west-southwest of Los Angeles, California. The geography of the Hawaiian Islands is defined by their volcanic history, and the Big Island is home to three active volcanoes, one dormant volcano, and one extinct volcano (Briney 2016). Two volcanic peaks dominate the terrain in Hawaii County; both top out at over 13,000 feet. Climate differs significantly between the windward (Eastern) and leeward (Western) sides, with the former defined by lush tropical forests with heavy annual rainfalls. On the Leeward side, the terrain is arid, with climate similar to the deserts found in the continental US (Briney 2016). Figure 1 clearly depicts the stark contrast between the brown 'dry side' and the green 'wet side' of the island.

Figure 1 Hawaii County, Hawaii (Google Earth 2016)

Hawaii County was selected for this study primarily because of the author’s residence on that island. Additionally, the Marine helicopter mission planners that produced the initial HLZ surveys serve with Marine Light Attack Helicopter Squadron 367 (HMLA-367), based at Marine Corps Air Station Kaneohe Bay, on the nearby island of Oahu, Hawaii. Numerous natural disasters have struck the Big Island, with ten earthquakes, six volcanic eruptions, and five tsunamis occurring in the last century (Timetoast 2016), making it a particularly suitable location for this study. Cyclonic activity in the central Pacific has impacted Hawaii County in the past, even when these large storms did not directly strike the island. Flooding due the torrential rains associated with Hurricane Dot in 1959 cause significant damage in the county (Central Pacific Hurricane Center 2017). As depicted in Figure 2 Hawaii is located where teleseismic tsunamis from the around the Pacific have impacted Hawaii over the centuries. Within the larger area of the island, three towns were chosen for this study’s surveys: Waimea, Honokaa, and Pahoa.

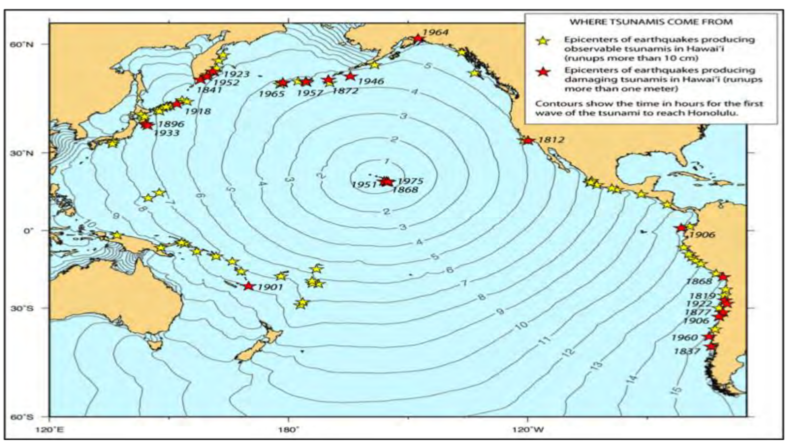


Figure 2 Hawaii Impactful Tsunami Origins (Pacific Tsunami Warning Center 2017)

1.1.1. The Town of Waimea

The town of Waimea was selected because it best represents the more benign segments of the study area, with little impact felt from hurricanes, tsunamis or volcanic activity. Waimea is a town of approximately 10,000, sitting in the high saddle between the extinct Kohala Volcano and the dormant Mauna Kea Volcano in the northern part of Hawaii County. In its past a company town supporting the sprawling Parker Ranch cattle operation, Waimea has transitioned in recent years to a more diverse economic and demographic base. The town is located at approximately 2,500 feet above sea level. The terrain in Waimea is largely flat, with some rolling terrain, with high ground from the slope of the Kohala Volcano to the north, and gentle slope down to the west (Hawaii Tourism Authority 2017). Figure 3 depicts Waimea.

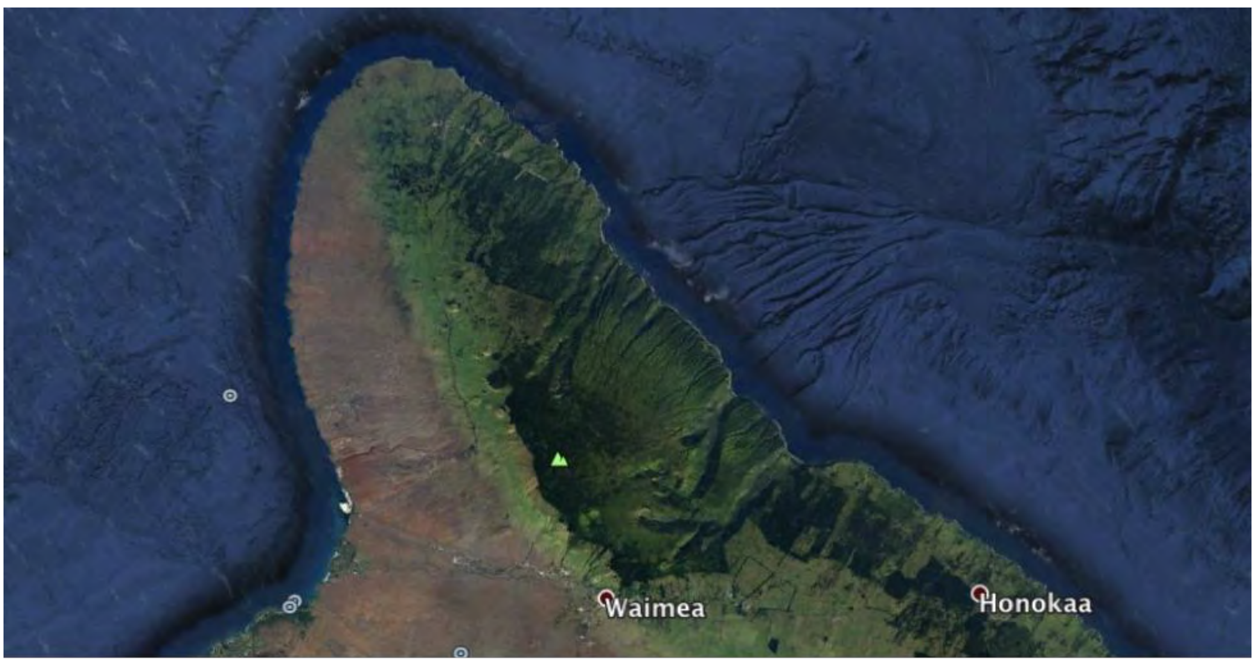


Figure 3 Northern Towns of the Study Area (Google Earth 2016)

1.1.2. The Town of Honokaa

Honokaa was selected because it represents a portion of the study area that is more susceptible to the disaster effects of hurricanes, as it is located on the windward side of the island. Honokaa represents the ‘wet’ side of the Big Island for this study. Formerly a company town for the huge sugar cane plantations that dominated this part of Hawaii County in the past, this sleepy village of approximately 2,500 now supports people that commute to jobs in the city of Hilo, forty miles to the south. Honokaa sits on terrain that is much more complex than that found in Waimea. Sited approximately two kilometers inland from the steep shoreline cliffs of the Hamakua Coast, this town is at approximately 1,000 feet above sea level. Steep downhill slopes to the northeast define the topography of the town, which might prove challenging during the selection of potential HLZs (Hawaii Tourism Authority 2017). Figure 3 above depicts the town of Honokaa.

1.1.3. The Town of Pahoa

Pahoa was selected for study at the recommendation of the volunteer HLZ surveyors, as it is well known locally as an area most likely to be impacted by the effects of the various natural disasters that Hawaii County might experience. Much like Honokaa, Pahoa was born out of the boom on timber (and later sugar) on the Big Island, but has since seen its fortunes decline, only to rebound with the advent of tourism to the volcanic regions. This town of less than 1,000 residents sits approximately 10 kilometers from the coast on the southeastern portion of the Windward Side of the Big Island (Hawaii State Info 2017). Pahoa receives over 150 inches of rain per annum on average, making it not only the sixth-rainiest town in the United States, but also the target of potential flooding effects (Hawaii State info 2017). Situated only 20 kilometers to the east of Puʻu ʻŌʻō, a very active lava vent in the Kīlauea volcano's East Rift Zone, Pahoa exists under constant threat from volcanic activity, as depicted in Figure 4, where the dark lava flows approaching the town from the southwest are clearly visible. A simple search for the term "Pahoa" on the USGS Volcano Hazards Program website yielded 21 instances of it being named in the hazard zone of volcanic activity since the start of 2015, with houses and streets being threatened by encroaching lava flows (United States Geological Survey 2016).

Figure 4 Pahoa Study Area (Google Earth 2017)

Additionally, Pahoa loses use of many of its roads in instances of cyclonic activity, as an invasive species of tree, the albizia (falcataria moluccana) looms over many of the main roads. The albizia readily topples in high winds due to its shallow root structure and broad canopy.

Figure 5 depicts response efforts to clear very large albizia trees downed by Hurricane Iselle in 2014 (Island Trust Properties 2017).

Figure 5 Workers Clearing Albizia Trees in Pahoa 2014 (Associated Press 2014)

1.2. OpenStreetMap (OSM)

OpenStreetMap serves as an integral element of this research project, as the crowdsourced HLZ survey data shall be uploaded to OSM for validation and use by helicopter aircrews. OpenStreetMap began in 2004 as an initiative to develop and publish a crowdsourced map of the United Kingdom (UK) (OpenStreetMap Contributors 2017). 2006 saw the establishment of the OpenStreetMap Foundation, a UK-based non-profit entity supporting the OSM Project (OpenStreetMap Contributors 2017). OSM active involvement in the response to the 2010 earthquake in Haiti spawned the Humanitarian OpenStreetMap Team (HOT), which since that time has been very active in developing and providing (free of charge) accurate and up-to-data maps in support of agencies and organizations conducting HA/DR operations (OpenStreetMap Contributors 2017).

1.3. Motivation

Multi-faceted motives exist for this research. As indicated in the dedication at the start of this manuscript, the author has powerful personal motivation to see that the work of helicopter crews in HA/DR is made safer. Humankind around the world would benefit from this research, as the HA/DR could be executed more efficiently and effectively. Scholarly research into the accuracy and validity of VGI would be advanced by this study.

1.3.1. Benefits to the Study of GIS

This research will continue efforts that originated with Goodchild nearly a decade ago (Goodchild 2007) looking at the impacts that crowdsourced, volunteered geospatial data can have on GIScience. The positive aspects of crowdsourcing geospatial data will be further analyzed, and many of the findings in the narrow field of this thesis will be applicable in the broader realm of GIScience. While there have been studies of GIS techniques for HLZ selection (Doherty, Guo, and Alverez 2013) none have merged the rapidly growing resource of crowdsourced data collection with surveys of these critical areas of disaster response architecture. Additionally, challenges and disadvantages of crowdsourced geospatial data in HLZ surveys during disaster response operations will also be studied, and these conclusions will also be relevant to the greater study of GIScience. These efforts will add to body of work that has assessed the accuracy and effectiveness of volunteered geographic information (VGI) (Haklay

2010), focusing on a narrow, technical data set collected by volunteers in the aftermath of a disaster.

Crowdsourced geospatial data collection disaster response will be studied further, taking a look at how these countless additional sensors can be leveraged to assist in surveys of HLZs. Crowdsourced data has proven invaluable in focusing disaster operations, with noteworthy success in Haiti in the aftermath of the 2010 earthquake (Heinzelman and Waters 2010). Additionally, the challenges and disadvantages of crowdsourced geospatial data in HLZ surveys during disaster response operations will also be studied, and mitigation strategies and integration technologies will be proposed, implemented, and assessed for effectiveness.

1.3.2. Benefits to Society

This research shall benefit society as a whole, as it will lead to more efficient and effective employment of vertical-lift assets during disaster response operations. Vertical lift assets include both traditional helicopters and tilt-rotor aircraft such as the MV-22 Osprey. Studies have been conducted on GIScience methods for planning helipad locations for medical evacuation (Foo, et al 2010) and landing zones for Search and Rescue (Doherty, et al 2013). There is a research gap related to GIScience application to the survey and selection of Helicopter Landing Zones during disaster response operations.

1.3.3. Benefits to Helicopter Aircrews

Some of my motivations for carrying out this study are a blend of professional and personal. As a career military helicopter pilot, I had occasion to plan for support to disaster response operations on several occasions. Simple timing prevented me from actually executing those plans, but many of my colleagues did so. Both the planning process and anecdotal information shared by those comrades who did provide support to disaster response operations indicated that timely and accurate data on HLZs was difficult to come by. This shortage of actionable intelligence about HLZs did not prevent helicopter support from going forward, but merely increased the associated risks, as other helicopter techniques that did not depend on HLZs were employed (Manwaring, et al 1998).

Perversely, military helicopter pilots are more likely to put themselves at risk during disaster response operations than in combat, likely due to a sense of altruism that may cloud sound judgment. Military helicopter aircrews will accept high risks in these situations in an effort to ease human suffering, sometimes to an extreme that cost them their lives. The aircrews may accept HLZ conditions that are near the margins of safe helicopter operations, landing on slopes that might exceed operating parameters of the aircraft, or on surfaces that are so dusty as to create hazardous 'brownout' conditions.

1.4. HLZ Planning with the Joint Mission Planning System (JMPS)

JMPS is a military GIS supported by Boeing, and used by aircrews and other mission planners for US and partner nation military forces. This GIS allows users to interact with and manipulate various imagery and digital elevation model (DEM) datasets. The National Geospatial Intelligence Agency provides the preponderance of this geospatial data, including National Imagery Transmission Format raster-product files and Digital Terrain Elevation Data (DTED). Additionally, JMPS can ingest and process commercial imagery products. JMPS supports the basic functions found in a commercial GIS, plus additional military-specific functions.

An effective HLZ possesses sufficient relatively flat terrain of dimensions that can support the number and type of helicopters planning to utilize it. The surface composition of the HLZ supports the weight of the landing helicopters, and that of the equipment and personnel used to load and unload them, while being free of fine particulate matter that can cause a brownout, or loss of visual reference for the aircrews (Phillips, Kim, and Brown 2011). Figure 6 depicts impending brownout conditions.

Figure 6 CH-47 Chinook Helicopter Impending Brownout (Phillips, Kim, and Brown 2011)

In an effective HLZ, the surrounding terrain lacks vertical obstacles that may prevent safe and effective ingress and egress by the helicopters. Those ingress and egress routes depend on prevailing winds and obstacles combining to allow the helicopters to land and takeoff heading into the wind, the most aerodynamically efficient flight profile. HA/DR HLZs exist to support the rapid influx of relief workers and supplies and the outflow of victims and survivors; the HLZs must be connected to effective transportation infrastructure. Conversely, security measures at the HLZs comprise a critical component of their effectiveness, protecting the aircraft and aircrew from an uncontrolled influx of refugees seeking aid, and safeguarding those same refugees from the hazards associated with operating helicopters.

1.4.1. HLZ Dimensions and Orientation Determination from JMPS

JMPS supports measurements of the horizontal dimensions of a HLZ through the use of standard GIS “ruler-type” measuring tools. JMPS users determined the orientation of the long axis of the HLZ using those same tools. The temporal quality of the imagery used in JMPS might impact the accuracy of the dimensions it produces; the effects of the disaster might have altered the terrain of the HLZ so significantly that its useable area effectively shrinks.

1.4.2. HLZ Winds Determination from JMPS

JMPS users planning HLZs depict winds on JMPS output products using drawing tools to create an overlay. The forecast prevailing winds are obtained from an external source such as a local weather office. Planners usually wait until just prior to mission execution to obtain the wind forecast, then add it to the HLZ diagram as an arrow showing direction, and a text box showing wind speed.

1.4.3. HLZ Vertical Hazard Determination from JMPS

Overlays are added to the base image in order to illustrate hazards such as the power lines highlighted in red along the northwest edge of the HLZ depicted in Figure 7. JMPS does not provide the user with the means of measuring the height of these vertical hazards, and in fact they are only located through the user's interpretation of shadows on the imagery. Vertical hazards that are depicted on aviation maps with relative and absolute elevation may be included in a JMPS HLZ diagram, as is depicted in the inset map of Figure 7.

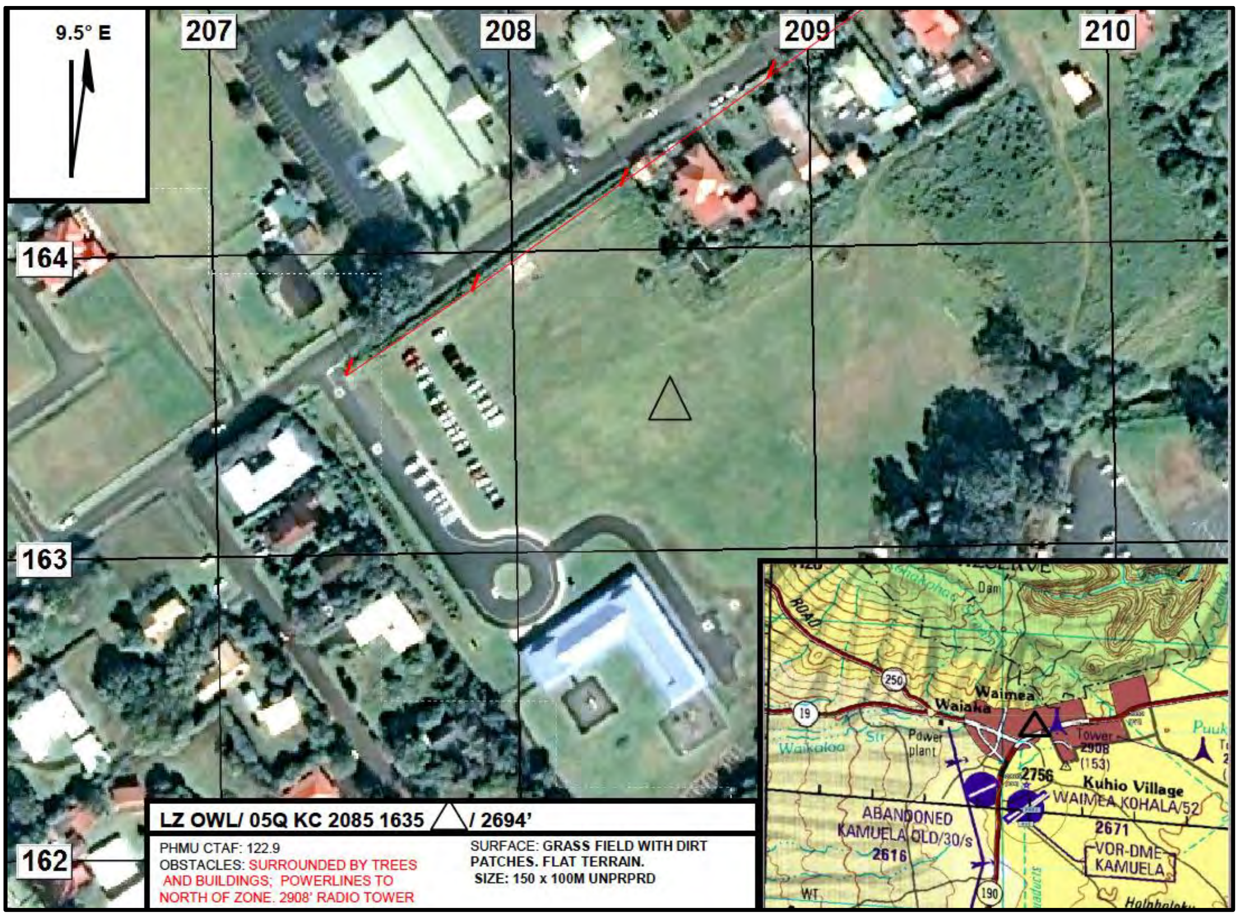


Figure 7 JMPS HLZ Diagram HLZ Owl, Waimea, HI

1.4.4. HLZ Slope Determination in JMPS

A safe landing at the base of a slope presents a hazard to personnel approaching the helicopter from the upslope side, as the main rotor clearance at the top of the slope may not be above head height, as is graphically depicted in Figure 8. Slopes beyond ten degrees are problematic, as they are close to or beyond the dynamic rollover angle for many helicopters. If a helicopter lands with an excessive cross-slope (which varies based on a number of conditions, including cross-winds, lateral offset of the aircraft center of gravity, and direction of the downslope relative to the aircraft longitudinal axis), a condition known as dynamic rollover may occur, causing the aircraft to roll over on its side, resulting in significant damage to the rotor system, drive train, and the helicopter in general (Schmid 1989).

Figure 8 Hazards of Sloped HLZs to Personnel (Department of Transport, Canada 2006)

1.4.5. HLZ Surface Composition Determination in JMPS

JMPS users estimate the surface composition of potential HLZs through examination of the color of the HLZ on overhead imagery. If the HLZ appears to be uniformly green, JMPS planners assess the surface to be grass, while terrain showing up on imagery as tan corresponds to sand or silt, both of which present potential brownout hazards to landing helicopters. JMPS imagery lacks sufficient resolution and detail to indicate whether the surface supports the weight of helicopters or the equipment and personnel loading and unloading them. Even if the JMPS user correctly assesses the surface composition via these crude remote-sensing methods, the temporal quality of that assessment directly depends on the age of the imagery used. Conditions related to the disaster might alter the surface composition well after the JMPS imagery was collected; for instance, the HLZs in the Pahoa study area could become blanketed in volcanic ash during a disastrous eruption.

1.4.6. HLZ Support Infrastructure Determination in JMPS

JMPS users assess the infrastructure supporting access to and from a HA/DR HLZ through the employment of the same ruler-type tools used for determining HLZ dimensions and detailed above. Trees and other vegetation overhanging roads in the vicinity of the HLZ might obscure this critical infrastructure from remote sensing systems, preventing accurate assessment by JMPS users. Even if the remote-sensing imagery possesses the quality and resolution to support an accurate assessment of the HLZ's supporting infrastructure by JMPS users, the temporal quality of that spatial data might detract from this analysis. Destructive factors related to the disaster might impact the critical infrastructure well after remote-sensing imagery supporting JMPS is collected; floodwaters associated with a hurricane might wash out or undercut roads in the Honokaa study area.

1.4.7. HLZ Security Posture Determination in JMPS

Utilizing remote-sensing datasets via JMPS in order to determine the potential security posture of a potential HLZ rests largely on the temporal quality of those data. Accurate assessments of active security measures, such as the presence of security personnel and manned access control points, depend on the data being collected in real-time, or near real-time. JMPS supports users identifying passive security measures (e.g., walls and fences) at an HLZ using remote sensing imagery, presuming that the imagery resolution is of adequate resolution. The destructive conditions associated with a disaster might degrade or destroy these passive security measures after the collection of the JMPS datasets.

1.5. Geospatial Workflow for Surveying HA/DR HLZs

Phase One of this project involved a collaborative effort with United States Marine Corps helicopter pilots, using their current mission planning GIS, to choose and plan HLZs for two small towns in Hawaii County, Hawaii. Phase Two was conducted using OSM, the most widely used VGI GIS. Phase Three focused on the development and refinement of straightforward, simple processes and tools, using materials readily at hand. In Phase Four, volunteers from the local populace with no background in GIS conducted surveys using the developed processes and tools, as well as provided feedback on the survey techniques. Phase Five consisted of experienced helicopter aircrews (including the planners from Phase One), conducting online reviews of the VGI-processed HLZs, and providing anecdotal feedback as to the effectiveness of the crowdsourced surveys.

1.6. Research Applicability

This research provides a detailed analysis of how simple, straightforward survey tools used by volunteers can enhance the effectiveness of traditional remote-sensing dependent GIS used for HLZ selection. Standardized processes and procedures for crowdsourced geospatial data collection and submission were developed, tested and validated. These processes and procedures have been made available to HOT for adoption and implementation worldwide, in response to future disasters. The desired end state of this research is the development and publication of standardized methods for volunteers to conduct and submit crowdsourced updates to pre-selected HLZ surveys in the aftermath of a disaster. Successful implementation of these methods would foster a synergistic melding of expert HLZ selection with VGI in order to yield the HLZs that provide the needed disaster response support in safest and most efficient manner possible.

1.7. Thesis Structure

This thesis consists of five chapters organized in the following fashion. Following this introductory chapter, Chapter Two contains an analysis of related scholarly work. Chapter Three outlines the planning and preparation required for the HLZ surveying conducted in this project. The HLZ surveys results and their subsequent validations reside in Chapter Four. Chapter Five contains the research conclusions and recommendations for further study.

Chapter 2 Related Work

Responses to disasters in the 21st century benefited from the use of crowdsourced geospatial data to enhance the data collected and processed by more complex GIS. This novel approach to disaster response led to the generation of research to analyze and document the associated processes. Relevant works exist on the methods by which VGI can be integrated with disaster response operations, and scholarly research has been completed on the networks used for movement of data to and from GIS during disaster response operations. Review of this applicable literature must include a study of VGI in a broad sense: how it is collected, collated, validated, and disseminated. Military forces are increasingly brought to bear during disaster response operations, and research into these efforts reveals impressive adaptive efforts by users to employ military GIS during these evolutions. Lastly, one must look at scholarly literature about the applied science of using remote sensing and other surveying techniques for HLZ selection and surveys.

The last decade has seen explosive growth in the use of VGI in all realms of human endeavor. While there has been an understandable lag, the growth in scholarly research related to VGI employment during disasters has been significant as well. However, this literature review has revealed that there is no work that directly addresses the role of VGI in HLZ surveys during disaster response operations.

2.1. Volunteer Geographic Information

VGI consists of crowd-sourced geospatial data collected by every day citizens with the intent of enhancing the greater collective geographic understanding of the world. The power of

VGI stems from its leverage of three concepts identified by OSM on it homepage: (1) Local Knowledge, (2) Community Driven, and (3) Open Data (OpenStreetMap Contributors 2017). Employment of humans as sensors provides a volume of data that could not be replicated with remote-sensing technologies in anything approaching a cost-effective fashion. However, challenges do exist in VGI; the dependence on the often-subjective human experience to serve as a means geospatial data collection requires study.

No study of crowdsourced geospatial data could overlook the seminal efforts of Dr. Michael Goodchild; his first look at the motivations behind VGI, the resultant accuracy of their work products, and the additive effect of this potentially massive data influx, drives much of following works on crowdsourced information in the GIScience realm (Goodchild 2007). The value of VGI becomes more evident with each instance in which it is responsibly integrated with remote-sensing and other traditional forms of geospatial data. VGI may enhance the accuracy of remote-sensing geospatial data, adding temporal quality to high-resolution imagery, depicting change and rate of change more effectively (Schnebele and Cervone 2013). Effective fusion of crowd-sourced data with the traditional data must follow a disciplined methodology in order to yield meaningful results, but these results can be significant (Schnebele and Cervone 2013).

2.1.1. Spatial Data Quality

Spatial data quality has been a concern in GIScience from its infancy. Much like other realms of information sciences, the quality of the output products directly correlates to that of the input data. Van Oort (2006) proposes a three-step process for assessing spatial data's suitability for use in a particular situation: (1) locate a dataset that embodies the information relevant to the particular application, (2) determine any usage constraints to employment of the dataset, and (3) ascertain whether the risks associated with spatial data quality are acceptable. Van Oort (2006) further identifies eleven elements of spatial data quality, which are detailed below in Table 1.

Table 1 Elements of Spatial Data Quality (Van Oort 2006)

Elements of Spatial Data Quality	
1. Lineage	Lineage for spatial data is; where the data came from, how it came to be, and what processes were used in its production.
2. Positional accuracy	Positional accuracy is the accuracy of the values of the pertinent coordinates.
3. Attribute accuracy	Excluding temporal and positional attributes, these accuracies look at all of the other attributes of the data set.
4. Logical consistency	This element focuses on the relationships in the data set, and the consistency of their structure,
5. Completeness	At its extremes, completeness is an assessment as to the absence of pertinent data or the presence of superfluous data. A key component of completeness is an understanding the producer’s intent as to the scope of the data set.
6. Semantic accuracy	A broadly defined element, encompassing the interconnectedness of the other elements and includes uncertainties other than error.
7. Usage, purpose, constraints	Usage is how the user employs or exploits the data set. Purpose is the means of employment or exploitation the producer planned for the data set. Constraints are broadly defined to include direct costs, legal restraints for use and application of the data, and contractual limitations for data employment.
8. Temporal quality	Spatial data quality can be assessed temporally as expired, current, or not yet valid. Additionally, the time lapse between change in ground truth data and its representation in the data set is a critical component of this element.
9. Variation in quality	This element assesses variations in quality within the data set and the extent of uniformity within those variations.
10. Meta-quality	This element is an assessment of the quality of the data quality assessment itself.
11. Resolution	Resolution is often the starting point is collecting data for analysis, and this element can be a subset of the other identified elements.

Van Oort analyzes how the elements of spatial data quality might assist in decision-making. Decision-makers with a solid understanding of spatial data quality could implement risk mitigation measures to minimize the impact of low-quality data. No project possesses unlimited resources; planners must therefore determine what the level of spatial data quality is required for successful execution of the project, balanced against the costs in terms resources, time, and labor to achieve that level of quality. Cost-effective measures to validate crowdsourced data may then be developed and implemented in order to achieve that goal.

2.1.2. Spatial Data Quality in VGI

Concerns over the validity of VGI persist since the earliest instances of its use. Scholarly work in this realm reveals that VGI can be of high quality, but variances in quality can be quite large (Haklay 2010). Many of these variances stem from the efforts of discrete contributors, but these variances can be mitigated by the collection of geospatial data for a defined area by multiple volunteers (Haklay 2010). Flanagin and Metzger (2008) examine how credibility of the crowd-sourced data collectors defies a traditional definition of that term wherein credibility is based on a combination of expertise and trust. In the realm of VGI, credibility stems from believability, where perspective and opinion are more heavily weighted. These researchers view credibility not in terms of absolute scientific accuracy of the data being provided, but instead as a perceptual variable (Flanagin and Metzger 2008). For VGI employed in a disaster situation, the social and political implications linked to the believability of the crowdsourced information may outweigh the absolute, empirically measured accuracy of the geospatial data. While a detailed scientific analysis of numbers of refugees at two different feeding centers might indicate that the greatest good would be served by providing greater resources to the feeding center with the largest refugee population, the level of desperation within the smaller population (and, perhaps, its media exposure to the larger world) might indicate that priority support to it would be appropriate.

While numerous studies of OSM contributions find locational accuracy to be good, attribute accuracy, specifically of nominal attributes in VGI, can be subject to wide variances in quality (Van Oort 2006). Volunteers can readily misclassify attributes of a feature purely as a result of their cultural background or level of education – one man's creek is another man's stream. The benefits of the real-time or near-real-time temporal accuracy of VGI outweigh potential costs of inaccuracies of attribute data in that same crowdsourced geospatial data. If properly supported with data networks and processing systems to expedite dissemination and exploitation, the temporal quality of VGI can be extremely impactful to HA/DR planning. Terrain features directly impacted by the destructive mechanisms of a natural or man-made disaster may differ greatly from their pre-disaster condition. Volunteers providing ground-truth assessment of key terrain in the immediate aftermath of the disaster can replace "expired' data with "current" data.

2.2. VGI in Disasters

The first use of crowdsourced geospatial data in assessing the scope of a political crisis was in the Ushahidi (testimony in Swahili) project, which was inspired by the violence in Kenya following the elections in 2008, and provided a means for VGI to build a map of violent activity in that country (Ushahidi Website 2017). The first widespread use of crowdsourced geospatial data in HA/DR operations was in the immediate aftermath of the January 2010 earthquake that devastated Haiti. Heinzelman and Walters (2010) document both of these nascent crowdsourced disaster responses, specifically, how volunteers employed OSM in Haiti, and how the Ushahidi website shared spatial data. Their research documents the efficacy of volunteered geospatial collections, especially from individuals and teams that have received some measure of focused and relevant technical training.

These crowdsourced data collections were initially and largely georeferenced statements of need, with a shift later to geospatial data capture about the distribution of resources in refugee camps. The broad proliferation of mobile telephones in the Haitian population and the relatively rapid restoration of the wireless telephony in the country were critical elements of the success of crowdsourced support of HA/DR operations (Heinzelman and Waters 2010). While there were efforts to enlist volunteers in this latter effort, these volunteers were focused on trafficability of land routes, and status updates on refugee camps and feeding centers.

OSM established HOT and remained in Haiti for a year-and-a-half in an attempt to create effective and accurate geospatial products. Soden and Palen (2014) document this effort and argue that the development of an entrepreneurial spirit and a sense of ownership amongst the community of volunteer geospatial data collectors is critical to the project's sustained success (Soden and Palen 2014).

Zook et al. (2010) conduct a broader study of the role of crowdsourced geospatial data in the recovery efforts in Haiti. They provide a detailed examination of the technological environment in the realm of GIS and GIScience at the time of the Haitian earthquake. They take a more comprehensive look than Soden and Palen (2014) or Heinzelman and Waters (2010), at the volunteer geospatial efforts in the aftermath of the earthquake, all while applying a global perspective to the technical aspects of VGI. Of note, the authors identify that a majority of the world's population has access to a mobile telephone, but only a quarter of the world has access to the Internet (Zook et al. 2010).

The literature on VGI and crowdsourced data collection during emergency recovery efforts reveal no instances of or reference to HLZ surveys by lay persons or volunteers.

2.3. Data Networks in Disaster Response

First responder agencies cannot receive or employ VGI, regardless of its accuracy and precision, if data networks are not restored and sustained during disaster recovery operations. These networks are critical to the movement of VGI, and other data, in a timely and effective manner in the immediate aftermath of a disaster. Solutions to this challenge commonly consist of ad hoc responses, with human effort bridging the air gaps between disconnected networks (e.g., internet data and closed-loop military/government data systems). While often effective, this solution burdens HA/DR planners with additional labor, in a situation where resources are limited and tine is of the essence. At the Naval Postgraduate School (NPS), Peter J. Denning describes the conceptual network construct known as a Hastily Formed Network (HFN) that is ad hoc in nature, rapidly emplaced, and utilizes a variety of modern communications media (Denning 2006). Denning also emphasizes the human component of the HFN, coining the term "Conversation Space," where participants follow a set of rules for interaction within a certain communications medium (Denning 2006). The “HFN Puzzle” in Figure 9 is the work of Brian Steckler, a colleague of Denning’s at NPS, and it depicts the interactions and interfaces of the hardware, software, and expertise requirements for a HFN.

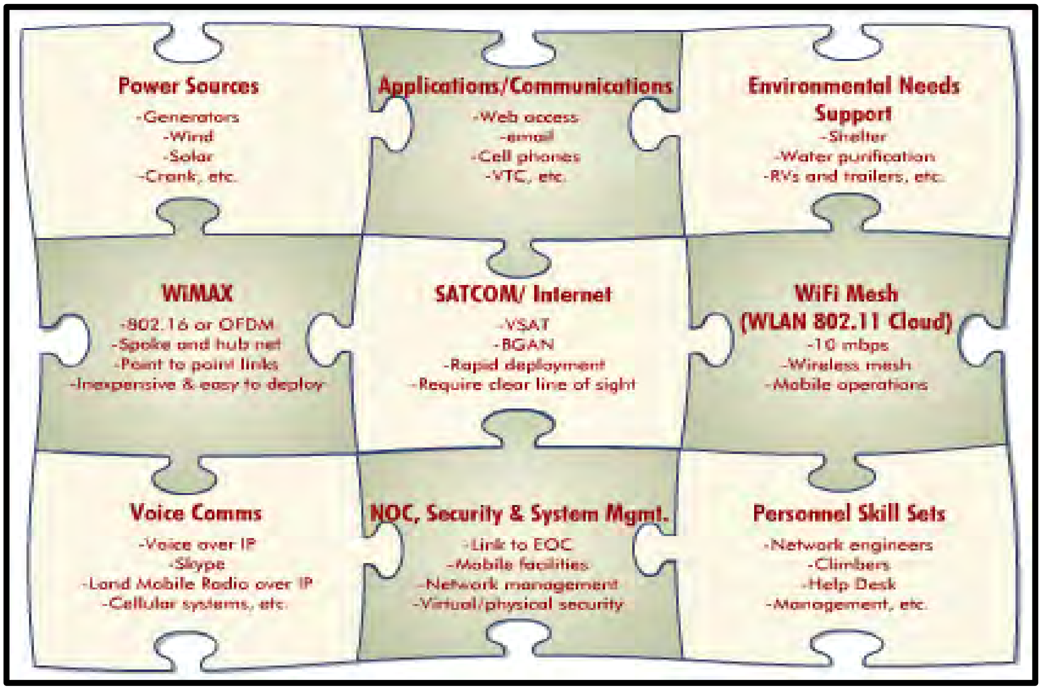


Figure 9 The HFN Puzzle (Steckler 2006)

Nelson, Stamberger, and Steckler (2010) expand on Denning and Steckler’s (2006) work on HFNs, looking at the evolution of these networks in the intervening years. The authors study the history of portable Internet Protocol (IP)-based networks, show where these networks have been employed in contemporary disasters, and forecast the future development roadmap for HFNs. They argue that four key constraints must be addressed by Information and Communications Technology (ICT) deployed to support disaster response, in that the solution must be: (1) small and lightweight, (2) commercially available (non-military grade), (3) energy independent, and (4) flexible (Nelson, Stamberger, and Steckler 2010). The authors merge Steckler's HFN Puzzle and Denning's nod to the human aspect of HFNs, presenting a model for HFNs for disaster response that is depicted in Figure 10. Effective HA/DR operations hinge on effective communications and data networks, and this subject has garnered attention from academic and operational communities. Progress towards a fielded solution proposed by the authors above remains elusive at the time of this research project; therefore the proposed geospatial workflow for volunteer HLZ surveys at the heart of this research project remains network agnostic.

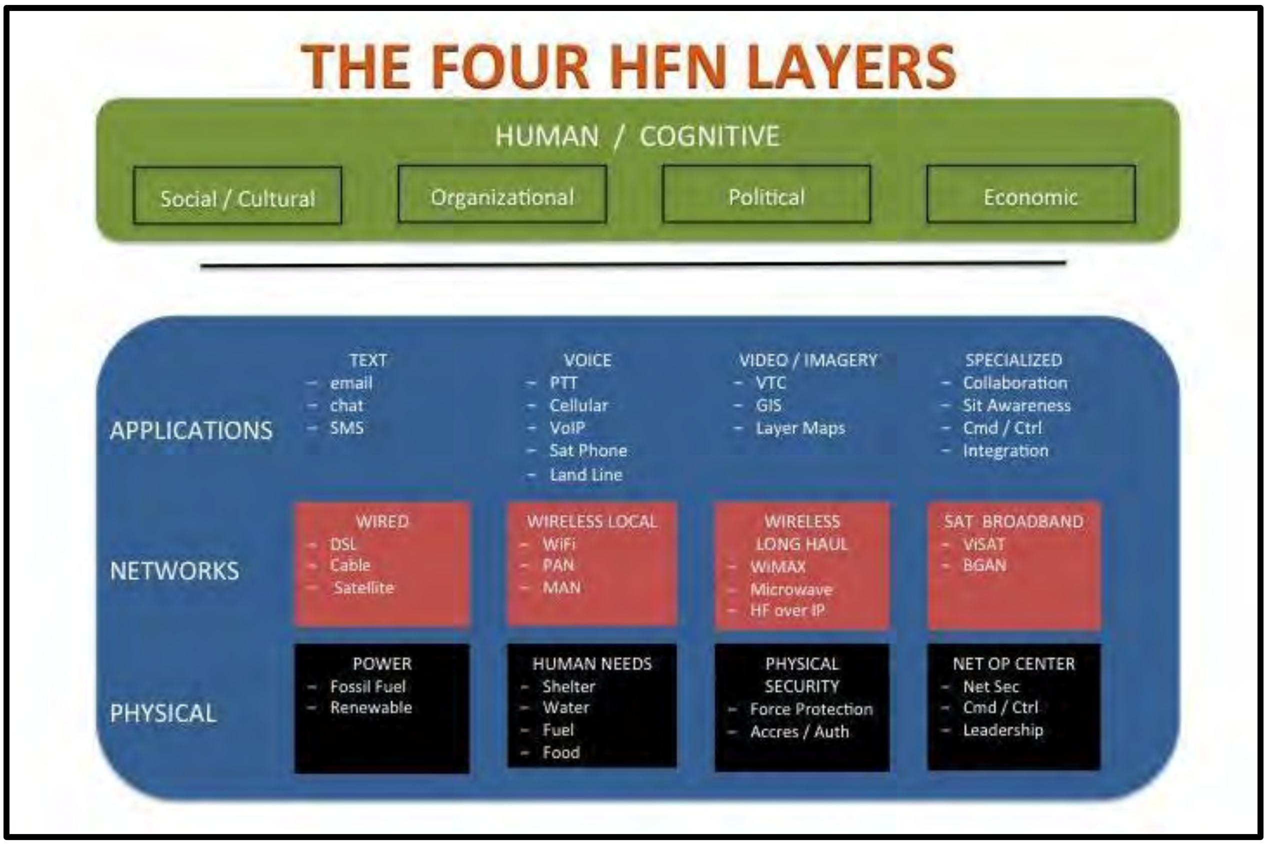


Figure 10 HFM Architecture Model (Nelson, Stamberger, and Steckler 2010)

2.4. Military GIS and Disaster Response

When one sets out to develop a geospatial workflow for volunteer HLZ surveys in support of HA/DR, the outputs of that workflow must be compatible with military geospatial workflows and GIS. Therefore, it is wise to look at how the military manages geospatial data across its operational spectrum. There will be a wide array of agencies supporting disaster response, including the military, which will supply the bulk of vertical lift assets (i.e., cutting edge tilt-rotor aircraft like the MV-22 Osprey, and traditional helicopters).[1] While there does not appear to be any research on linking crowdsourced geospatial data into military GIS, Fleming, et al. (2009) study military GIS employed in support of military operations in the littoral regions. However, their efforts are limited to using geospatial data to determine ground-based vehicle mobility, and they do not look at HLZ surveys.

Governmental agencies (such as FEMA) and military services were early adopters of computerized planning systems, especially GIS. Military planning GIS are designed to support the full spectrum of military operations, from the most benign of peacekeeping efforts through full-scale warfare. Recent events show civil-military GIS interoperability during HA/DR being expanded to include coordinated actions between military forces and civilian governmental and non-governmental agencies, with the most prominent example civil-military medical response to the 2010 Haiti earthquake (Auerbach et al. 2010). The interconnected nature of today's world necessitates the interoperability of different services within a nation's military and between the

[1] Observations based on the author's 22 years of experience flying as a Marine Corps Utility Helicopter Pilot, during which time he planned several HA/DR missions, and instructed on the topic at Marine Aviation Weapons and Tactics Squadron One, the US Marine Corps service-level equivalent of the US Air Force Fighter Weapons School, or the US Navy TOPGUN school.

militaries of different nations. It follows that the supporting GIS must support interoperability as well (Boukhtouta, et al. 2004).

The last few decades have seen militaries around the globe tasked with providing support to HA/DR operations. These non-combat missions have necessitated a paradigm shift for military leaders and their planning staffs. These personnel had to adapt military GIS designed to support conventional kinetic combat operations, finding ways to employ them for disaster response. The civil-military cooperation of HA/DR operations requires adaptive approaches to employment of GIS. Procurement and acquisition timelines for military GIS can be years, even decades, in length. Users of these military GIS continue to be creative in adapting these GIS to support HA/DR (Monaco 2014). However, it does not appear that there is any integration of VGI into these adaptive efforts.

Improvements of hardware and software capabilities of information systems occur at a pace so rapid that they easily outstrip large-scale, formal acquisition processes that are required for the procurement of new GIS. Given these circumstances, significant upgrades of military GIS are generated through direct action by the user community, with the formal acquisition programs of record left to catch up. In the 1990s FalconView, a GIS developed by the Georgia Tech Research Institute and operating on networked or standalone PC technology, stands as a prime example of this grass-roots development of a military GIS, where motivated members of the Air National Guard put in motion a decades-long evolution of a PC-based planning system that was regularly employed instead of the cumbersome and expensive UNIX-based “official” systems.

FalconView was immensely popular with US Air Force crews and with Navy and Marine Corps aircrews, resulting in the termination of the large-scale, expensive military GIS the services were using instead. The follow-on GIS, JMPS has a troubled reputation with its user community (Lindsey 2010), resulting in US military personnel looking elsewhere for solutions, including to commercial GIS such as Google Earth, and to rapid-prototype applications like the US Naval Air Systems Command KILSWITCH Android program. Military users strongly desire effective GIS to aid in the planning and execution of their missions, and would give serious consideration to the adoption of crowdsourced geospatial data if it could be proven valid and effective for the area of operations.

2.5. Helicopter Landing Zone Selection and Surveys

Analysis of recent and contemporary research of HLZ selection and surveys reveals the potential of emerging technology such as light detection and ranging (LIDAR) and computer modeling to aid in the remote survey of potential landing sites. The promise of these technologies remains limited by the low proliferation of these sensors and their associated processing systems. Even when available, these systems cannot determine certain critical details about the HLZs. Research shows that coupling modeling with professional surveys yields a synergistic effect, producing high quality HLZs.

Employing GIS to survey HLZs in support of HA/DR, specifically the employment of remote sensing technology such as LIDAR (coupled to a Digital Elevation Model (DEM)) can yield some locations that may support HLZs (Monaco 2014). However, there are limitations to this methodology, as LIDAR sensors are not widely proliferated, and might not be available in a timely manner to support HLZ surveys in the immediate aftermath of a disaster. Additionally, the most accurate DEM commonly available to military planners is Digital Terrain Elevation Data

(DTED) Level 2 (Pike 2016). DTED Level 2 is accurate enough to support navigation, but not precision operations such as targeting for weapon systems or level landing points for helicopters, which means that micro-terrain that could compromise the utility of a HLZ might go undetected. Lastly, the combination of LIDAR and DEM can do nothing to determine the surface composition of a HLZ; an otherwise perfect HLZ can be rendered untenable by the presence of sand, ash, or dust that can cause low/no visibility ‘brownout’ conditions.

Comparative analysis of methods for identifying HLZ suitability areas in Yosemite National Park juxtaposed modeling on an advanced GIS against a study of geospatial data by expert helicopter pilots (Doherty, et al. 2013). This study reveals that there is little measurable difference in outcome between the two, and if used in conjunction with one another the method are mutually supporting. 90.2 percent agreement exists on suitable sites between the two methods, and both are 95% successful at the classification of HLZs (Doherty, et al. 2013).

Foo et al. (2010) propose the use of GIS to select potential HLZ locations in support of Helicopter Emergency Medical Services (HEMS) flights. This study looks at all requests for HEMS support in the vicinity of Ontario, Canada in the calendar year of 2006. The resultant geospatial data is compared to the data for the established HLZs in the study area. From the intersection of these two datasets, gaps in the distribution of suitable HLZ sites are determined, and the construction of new HLZs are resourced to support historically demonstrated requirements. The authors leave to future researchers the task of using GIS to select sites for HLZ construction (Foo et al. 2010).

2.5.1. *Helicopter Landing Zone Survey Techniques*

Helicopter crews in general, and Marine helicopter crews in particular, prefer to land in HLZs that have been thoroughly surveyed. The preferred survey technique would entail the aircrews executing a personal ground-truth survey of the HLZ well before conducting a landing attempt. Barring that optimal circumstance, the next best option would be a ground truth survey conducted by military personnel who were trained on the requirements for conducting a HLZ survey, including the capabilities and limitations of various types of helicopters. Circumstances confronting military helicopter crews often prevent either of these ground truth survey techniques from occurring. In major combat operations, the presence or potential presence of enemy forces would make ground-truth surveys impossible. During HA/DR operations, conducting ground truth surveys would be difficult for other reasons. Getting helicopter aircrews or HLZ survey teams into a disaster-affected region would be costly in terms of time and logistics. Time spent by helicopter crews conducting ground truth surveys detracts from their primary ask of conducting disaster relief flight missions. Inserting HLZ survey teams into a disaster-stricken environment would obligate significant logistical requirements in a situation where all such support should be focused on the populace affected by the disaster. For these reasons, military helicopter crews conduct HLZ surveys using GIS using remote-sensing geospatial data.[2]

[2] Observations based on the author's 22 years of experience flying as a Marine Corps Utility Helicopter Pilot, during which time he planned several HA/DR missions, and instructed on the topic at Marine Aviation Weapons and Tactics Squadron One, the US Marine Corps service-level equivalent of the US Air Force Fighter Weapons School, or the US Navy TOPGUN school.

Chapter 3 Volunteer HLZ Survey Planning and Preparation

Optimally executed, this research produces a straightforward, easily understood and completed workflow that supports HLZ planning for HA/DR operations. This workflow commences with remote-sensing, GIS-generated, HLZ site selection and survey by professional helicopter operations planners. These planners transfer their results to the OSM HOT, which publishes these HLZs via the OSM Web GIS application. Government agencies and/or NGOs will perform two roles in this workflow: (1) ensuring volunteers receive training on the HLZ survey techniques, and (2) assigning trained volunteers the tasks of surveying particular HLZs, thereby ensuring no HLZs are omitted, or surveyed more than necessary. Volunteers will then execute ground-truth surveys of HLZs using easily understood techniques and procedures, and capturing results in simple terms. Volunteers will upload these results directly to the OSM Web GIS application or return the results of their surveys to the agencies that tasked them, which in turn upload them to OSM. Helicopter mission planners and aircrews can then access these refined HLZs on the OSM Web GIS application in preparing for and executing HA/DR support operations.

The audience for this research project therefore consists of three groups: government agencies and non-governmental organizations (NGOs) conducting HA/DR, volunteers surveying HLZs, and helicopter aircrews supporting HA/DR operations. Under current methods of planning and executing helicopter operations in support of HA/DR, the supported entities (governments and NGOs) identify the types and levels of helicopterborne logistical support required for HA/DR, and in what geographical location, which is then communicated to the supporting entities providing the helicopter assets. The mission planners and aircrews then use their standard GIS and planning processes (usually based on remote-sensing imagery and other geospatial data) to select and plan HLZs that address the supported entities' requirements. Validation and refinement of the selected HLZs begins with the initial helicopter mission to those sites, and continues through the duration of the overall operation. This process lacks initial effectiveness, and would benefit from the execution of credible ground-truth surveys prior to the flight of the first helicopter in support of the operation. The government agencies and NGOs coordinating the overall HA/DR effort require the logistical support to assistance and recovery be executed in a fashion that uses limited resources and time in the most effective manner possible. The people who choose to volunteer their efforts to support the HA/DR by crowdsourcing HLZ surveys require survey techniques and procedures that foster both straightforward comprehension and easy execution. The helicopter crews supporting the HA/DR operations require detailed geospatial data about potential HLZs that enhance safe and efficient employment of these HLZs. These helicopter crews conduct initial planning of HLZs, which provides volunteer surveyors with focused areas in which to conduct the ground truth surveys. These initial HLZs, and the subsequent results of the ground truth surveys, would be communicated between aircrew and surveyor by the government agencies and NGOs. This research project endeavors to generate a straightforward and easily executed volunteer HLZ survey workflow, which can then be promulgated to the target audiences identified above for employment in HA/DR operations.

To support the target audience in the satisfaction of their collective requirements, this research project consisted of five phases. Phase One involved United States Marine Corps helicopter pilots, using their current mission planning GIS, selecting and planning HLZs for three small towns in Hawaii County, Hawaii. Phase Two utilized OSM, the most widely used crowdsourced GIS, to upload the outputs of Phase One for follow-on use by the volunteer HLZ surveyors. Phase Three involved the development of survey techniques and procedures, with careful consideration given to the limited training and resources available to a volunteer in a post-disaster environment. In Phase Four, volunteers employed the techniques and procedures from Phase Three in order to assess the pre-surveyed HLZs and annotate and validate their utility, while also providing feedback to the researcher for improvement of those processes. Phase Five consisted of professional helicopter aircrews reviewing the results of the VGI-processed HLZs, and then providing feedback as to the effectiveness of the crowdsourced surveys. Figure 11 depicts this workflow, with the elements discussed in this chapter highlighted. Adaptation of this workflow to real-world contingencies should yield efficiencies in the execution of helicopter operations under these circumstances. Over time, this workflow will evolve to even greater effectiveness, as the target audiences will identify shortfalls and develop more efficient techniques.

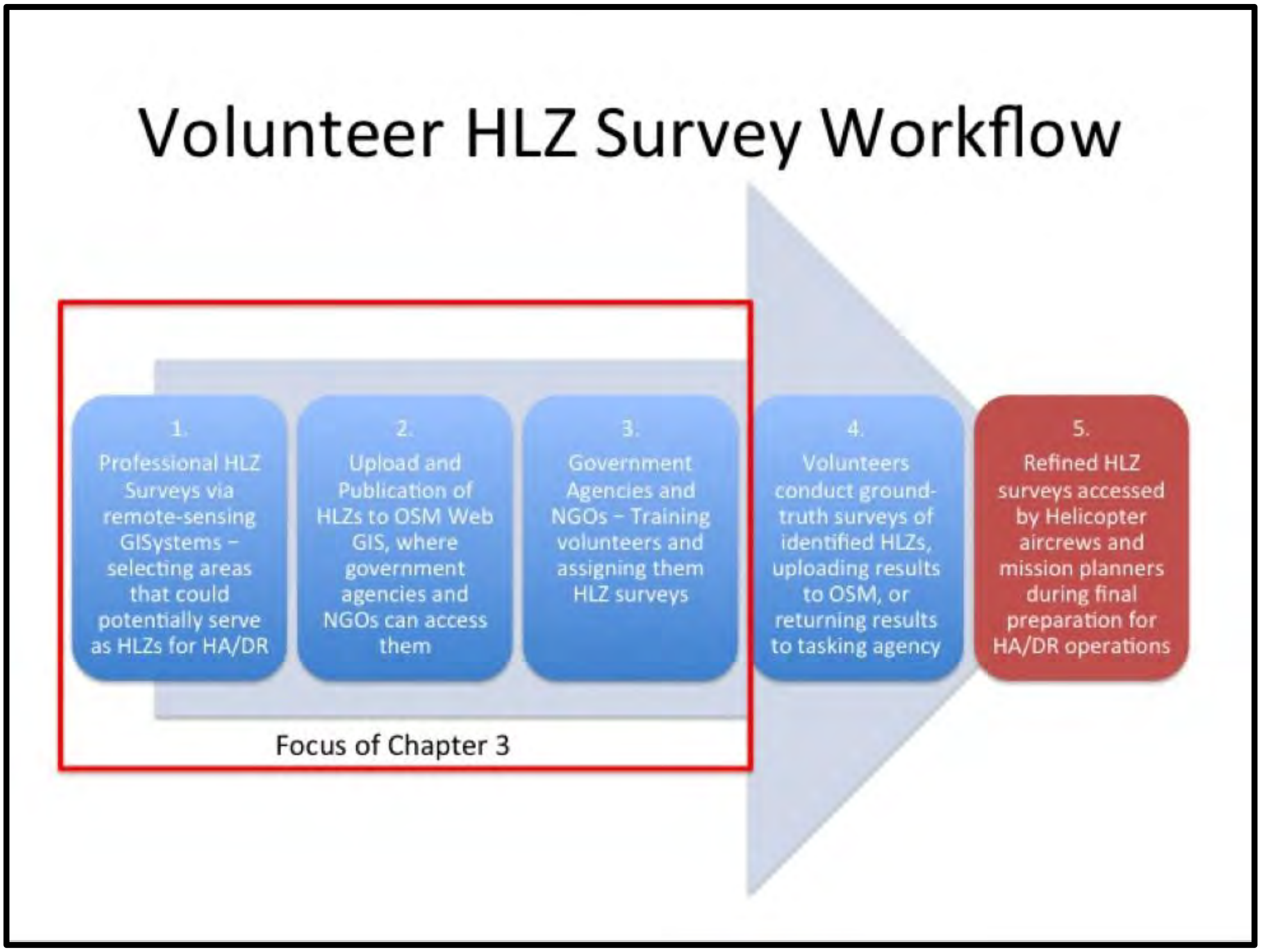


Figure 11 Volunteer HLZ Survey Workflow

3.1. Phase One - Development of Professional HLZ Surveys

The UH-1Y "Venom" helicopter crews of HMLA-367 executed the initial efforts of Phase One. These aircrews executed a scenario generated by the author whereby their mission was to plan HLZs to support HA/DR in the three towns of the study area. During the weeks of 26 December 2016, these helicopter crews conducted HLZ surveys within a two-kilometer radius of the centers of the towns of Waimea, Honokaa, and Pahoa in Hawaii County. At the direction of the researcher, these planners chose HLZs that were sufficient to support a flight of two UH-1Y helicopters. A HLZ supporting two of these smaller helicopters (or similar-sized UH-60 Blackhawks) would also support a single MV-22 Osprey tiltrotor aircraft or a single heavy-lift helicopter such as a CH-47 Chinook or a CH-53 Super Stallion. In other words, a HLZ developed for two UH-1Ys represents planning efficiency, as it can support single-ship landings by other, larger helicopters. The author limited the HLZs to a two-kilometer radius from the center of each town for two reasons: to bound the problem for the Marine aircrews, and to limit the HLZs to sites that disaster survivors in those towns could easily reach on foot.

The HMLA-367 helicopter crews used the JMPS to develop the initial HLZ surveys for Phase One. When planning the Phase One HLZs, the Marine aircrews used color satellite imagery to generate the base layer. DTED was used along with some drawing and labeling tools to generate the layers that combine with the base to create the composite HLZ diagram. Long standing tradition, codified in military standard operating procedures, calls for HLZs to be named after birds (e.g., HLZ Hen).

3.1.1. General description of HLZ diagrams generated by HMLA

The helicopter mission planners from HMLA-367 selected a total of nine potential HLZs in the study area: three each in Waimea, Honokaa, and Pahoa. The end product produced by HMLA planners consisted of a series of HLZ diagrams. An HLZ diagram contains JMPS remote-sensing imagery, annotated with layers for elevation and the Military Grid Reference System (MGRS), and includes text boxes for additional data about the HLZ. These data depicted in the text boxes contain information regarding applicable communications frequencies, estimated surface slope (at least, expected slope direction), vertical obstacles, and surface composition.

The HLZ diagram displays the HLZ location in MGRS, as the US Department of Defense uses MGRS as its default coordinate reference system. MGRS provides a wholly unique alphanumeric expression for any particular point on the earth's surface, derived from the Universal Transverse Mercator (UTM) coordinate system (National Geospatial Intelligence Agency 2017). HMLA planners included a MGRS overlay on the HLZ diagram in order to provide helicopter aircrews with a means of quickly deriving a grid coordinate in the vicinity of the HLZ. Planners included HLZ elevation expressed in feet above mean sea level, as aircraft instruments indicate altitude in feet.

Planners possess latitude regarding the format and content of the additional information listed in the text box overlays. Statements regarding surface slope vary from descriptions of direction ("upslope to the northwest" vs. "downslope to the southeast.") to estimates of magnitude stated in general terms ("large slope"). Surface composition statements consist of planners estimates based on their subjective interpretation of the remote-sensed imagery; a uniform green surface is assessed to be grass. Earth-colored patches on the imagery of the HLZ are assessed to be exposed dirt. Some of these analyses correspond to a contextual assessment; a baseball diamond will have a manicured grassy outfield and the infield with be packed dirt. Planners might graphically highlight the vertical obstacles that they discern from imagery, and also indicate their distance and direction from the HLZ, along with the estimated height. Figure 12 depicts an HLZ Diagram prepared by the HMLA planners for this project. Appendices A and B contain all of the HLZ diagrams produced by the HMLA planners.

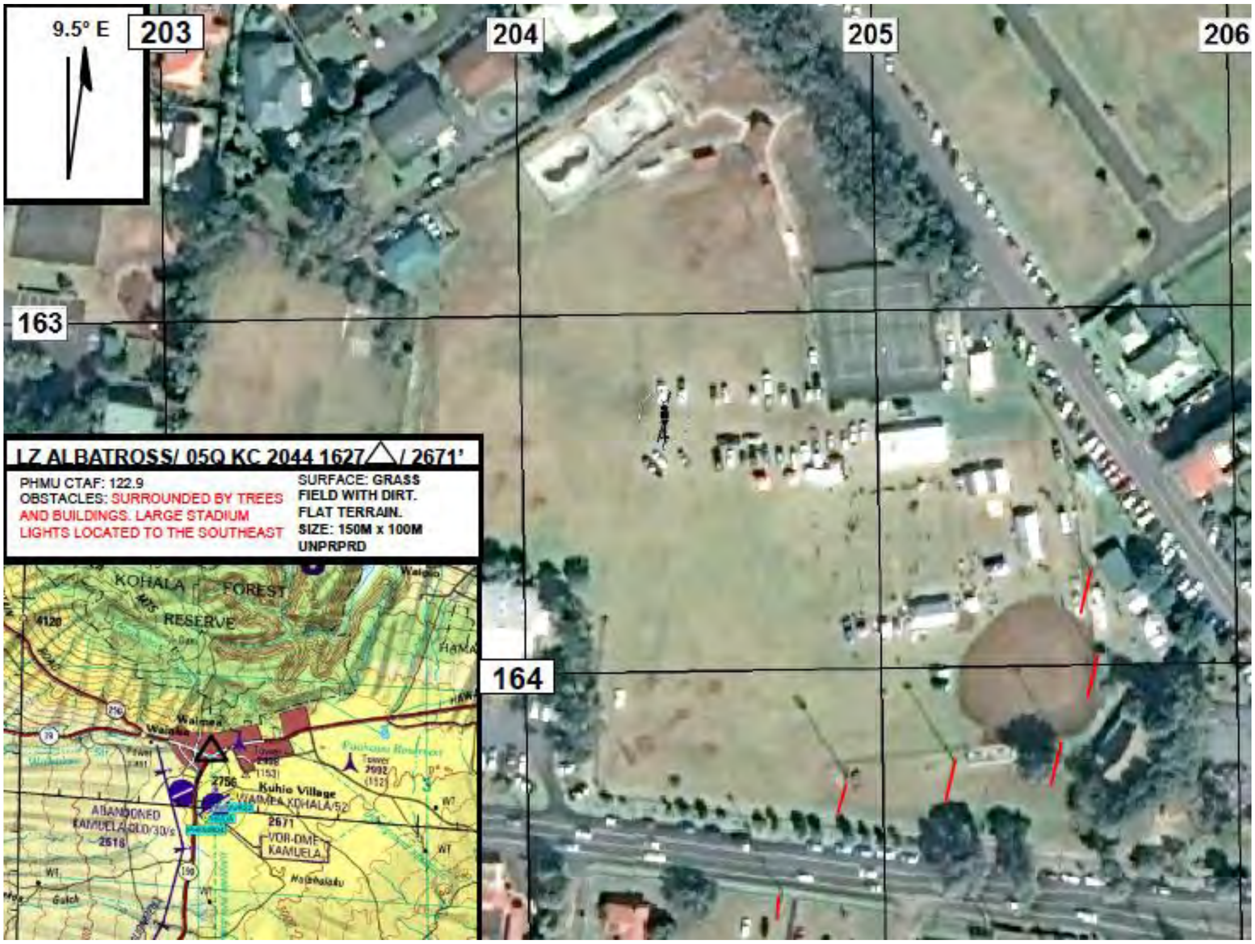


Figure 12 JMPS HLZ Diagram HLZ Albatross, Waimea, HI (Dieska 2016)

3.1.2. Manual Conversion of JMPS HLZ data to support upload to OSM

HMLA planners did not optimize the HLZ data for upload to OSM, but instead presented it in the graphic format used in HA/DR mission briefings and during the execution of flights. In order to best support upload of the HLZs to OSM, the author converted the format of some HLZ data, and manually transcribed data from the diagrams’ text boxes. This text data was transcribed in all lower case letters, with the intent that surveyor refinements would be in all capital letters, allowing an end-user to easily differentiate the source of data displayed in the comment field of the HLZ in OSM. Table 2 depicts the HLZ data after conversion to OSM-compatible formats.

Table 2 JMPS HLZs in OSM Compatible Format

HLZ Name	Location	Elevation	Dimensions	Description
OWL	20.0238739°, -155.6682637°	2694' MSL	150 X 100M	grass field with dirt patches, flat terrain. surrounded by trees and buildings. powerlines north of zone 2908' tower 1.5nm west
ALBATROSS	20.0230926°, -155.6721673°	2671' MSL	150 X 100M	grass field with dirt patches, flat terrain. surrounded by trees and buildings. Large stadium lights located to the southeast
PEREGRINE	20.0286515°, -155.6985331°	2457' MSL	100 X 100M	grass field (baseball diamond). surrounded by trees to the north south zone enclosed by a fence. north to south descending terrain.
PARAKEET	20.0747413°, -155.4672826°	1181' MSL	100 X 75M	grass soccer field. rising slope in southwest corner. bordered by trees to south. large stadium lights to northwest of zone
DUCK	20.0763348°, -155.4631022°	1145' MSL	100 X 75M	grass football field. south to north descending terrain. Football goal posts located on east and west ends of zone. large stadium lights surrounding zone
EMU	20.0737984°, -155.4701351°	1276' MSL	200 X 100M	grass field with dirt patches. south to north descending terrain. trees to the west of zone. large slope from south to north
HUMMINGBIRD	19.5015554°, -154.9349924°	571' MSL	575 X 450M	scrubgrass with isolated trees. upslope northeast to southwest
MACAW	19.4895732°, -154.9572340°	735' MSL	980 X 350M	scrubgrass and lava rock, upslope northeast to southwest 50 foot trees around zone, road in the middle of zone
PARROT	19.4842222°, -154.8912574°	614' MSL	800 X 900M	powerlines north of zone. tower to north of zone trees border zone on west. shrubs in zone

3.2. Phase Two – HLZ Uploads to OpenStreetMap

In Phase Two, the OSM Web GIS application served as a common repository for the pre-surveyed HLZs from Phase One. During the week of 31 October 2016, a email thread with the President of HOT Board of Directors and others involved in the HOT indicated that there was a great deal of support and interest for this project. HOT efforts in this area during the Nepal earthquake response in 2015 suffered from a HOT-identified lack of a standardized process, and they seek to address this shortfall. Follow-on teleconferences and videoconferences with OSM HOT members aided in the development of upload methodology.

3.2.1. Manual Upload of HLZ data to OpenStreetMap

OSM Point nodes supported the inclusion of additional data regarding the HLZ name, elevation, and a note regarding the association of these HLZs with a thesis research project. Figure 13 below depicts the input screen where these data could be uploaded to OSM, using HLZ Owl in Waimea as an example. The OSM application front end allows users to view an HLZ once it has been manually loaded into OSM. Figure 14 below presents HLZ Owl as displayed in OSM after manual input. Input was straightforward, and took less than five minutes to complete.

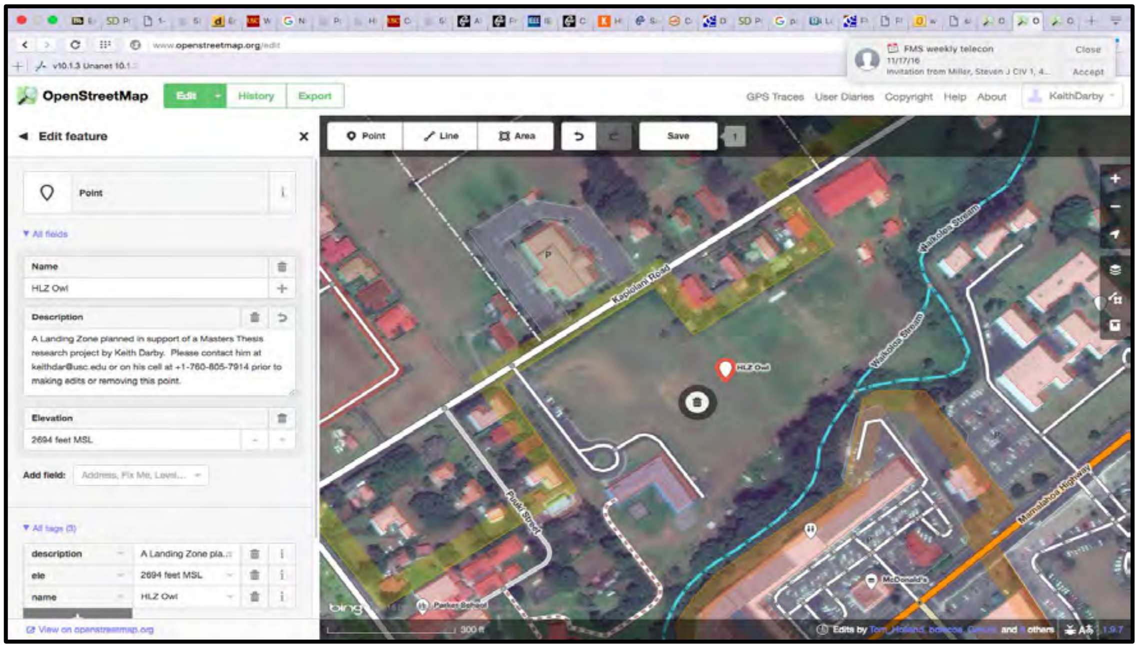


Figure 13 OpenStreetMap Point Input Screen - HLZ Owl (OSM 2017)

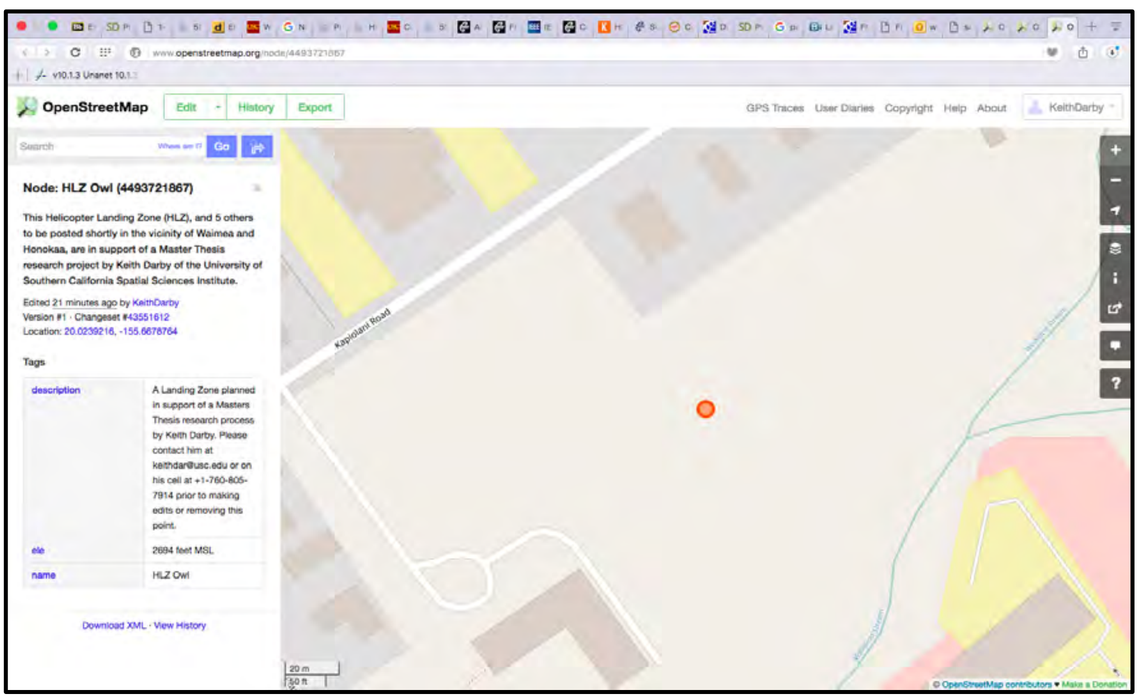


Figure 14 OpenStreetMap Display Screen - HLZ Owl (OSM 2017)

The inputs appear in the “Standard” layer of OSM within 2-3 minutes of upload, with additional time passing before they appear in additional layers, such as the “Humanitarian” layer (OpenStreetMap Contributors 2016).

3.2.2. OSM Improved Import Process for HLZs

The manual input process suffices for an initial effort, but tailoring the inputs to more easily support automated or semi-automated importation shall be pursued. Additionally, while a ‘Helipad’ option exists for the Point inputs menu in OSM, there are no additional data fields available for the user beyond Name, Address, Description and Elevation (OpenStreetMap Contributors, 2016). Coordination has been initiated with the HOT to add a HLZ standard to the Point input menu, which would include fields that expert helicopter planners would want to see imported from their efforts on formal GIS such as JMPS. These additional fields may include: initial slope assessment, initial surface composition assessment, and nearest known vertical hazards. The desired endstate of this effort would be the OSM GIS supporting detailed and accurate HLZ data inputs from helicopter planners from agencies supporting disaster relief operations. HOT representatives acknowledged that the Helipad Function of OSM lacked the detail needed for HA/DR, as that function was designed to document prepared single-helicopter landing sites that might not support these operations.

3.3. Phase Three – Development and Training of the Volunteer HLZ Survey Process

Phase Three focused on the development of simple and straightforward processes and procedures for volunteers to employ for HLZ surveys. These techniques and procedures are based on processes that can be easily grasped by an untrained volunteer, executed with tools that would be readily at hand in a post-disaster environment, and documented with pen and paper. Table 3 below depicts the elements and workflow of the volunteer HLZ survey process.

Table 3 HLZ Data Collection Methods and Documentation Techniques

Data	**Collection Method(s)**	**Documentation Technique**
Surface Slope	Manual survey techniques	Text
Surface Composition	Visual Observation	Text
Prevailing Winds	Flag Observation Method; Dropped Paper Method	Text
Hazardous Micro-terrain	Visual Observation	Text
Vertical Obstacles	Visual Observation and estimation techniques	Text
HLZ Security Posture	Visual Observation	Text
HLZ Infrastructure	Visual Observation	Text

3.3.1. Surface Slope Estimation Techniques

Surface slope estimation does not require complex and expensive survey tools and associated training. The Future Famers of America conducts regular competitions in Land Judging; a sub-element of this competition consists of slope estimation. Surveyors establish the slant distance from the top to the bottom of the slope, and then use a straight edge or their outstretched hand to estimate the vertical change between the top and bottom of the slope (Edmonds, et al. 1998). Collection of these two dimensions supports the performance of simple trigonometry to calculate the slope. HLZ surveyors would estimate slant distance using a measured pace count, and vertical change using the height of a known object (e.g., a fellow volunteer) as a unit of measure. Figure 15 graphically depicts this slope estimation technique.

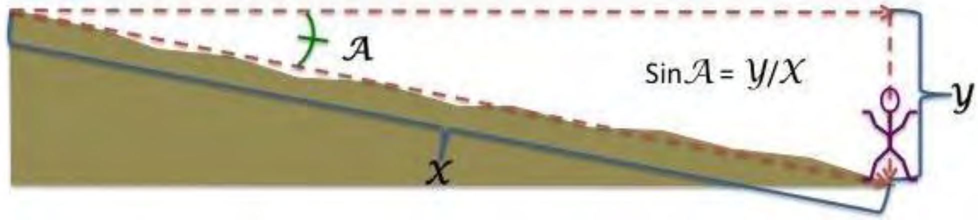


Figure 15 Slope Estimation Technique

3.3.2. Wind Velocity Estimation Techniques

The United States Army teaches three techniques for wind estimation in support of basic rifle marksmanship. The most effective of these techniques employs a flag, whereby the flag's estimated angle in degrees relative to its flagpole can be divided by four, the quotient yielding the wind speed in miles per hour. The least effective technique estimates wind velocity through subjective observations by a soldier. The pointing method utilizes a piece of paper or some other readily available light object, that the soldier would drop from shoulder height, and then point at its point of impact on the ground. The soldier would divide the resultant angle by four, yielding the wind speed in miles per hour (United States Army 2003). Figure 16 depicts the pointing method for wind estimation.

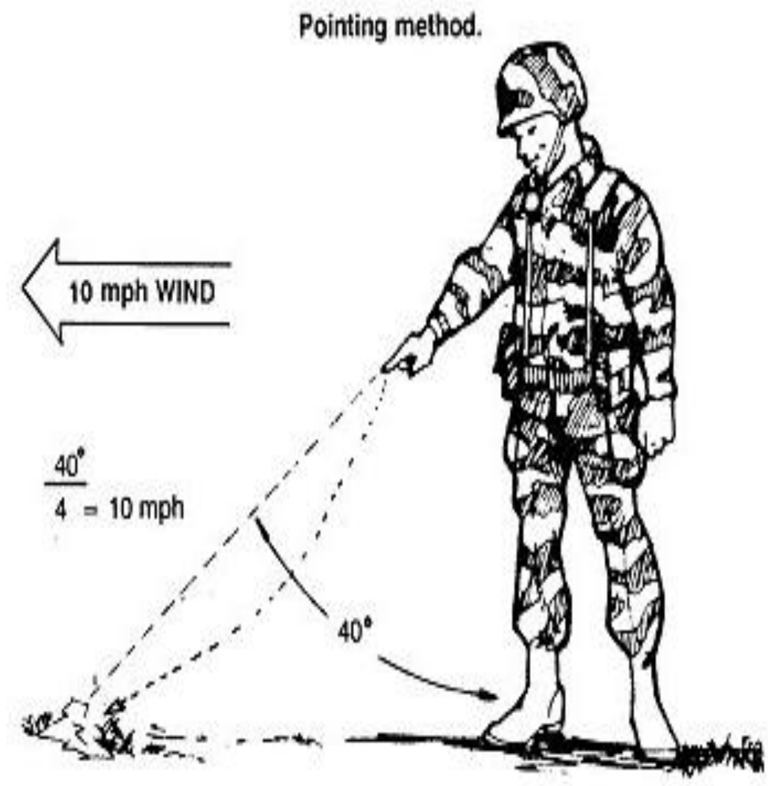


Figure 16 Pointing Method for Wind Estimation

3.3.3. Vertical Hazard Height Estimation Techniques

Volunteers estimate the height of vertical obstacles in the vicinity of an HLZ using a defined object's height as a unit of measure. The surveyor uses an object of known height (e.g., a fellow volunteer) in the vicinity of the vertical hazard as a "ruler," measuring the obstacle in numbers of rulers. Figure 17 depicts the Unit of Measure technique for estimating the height of vertical obstacles.

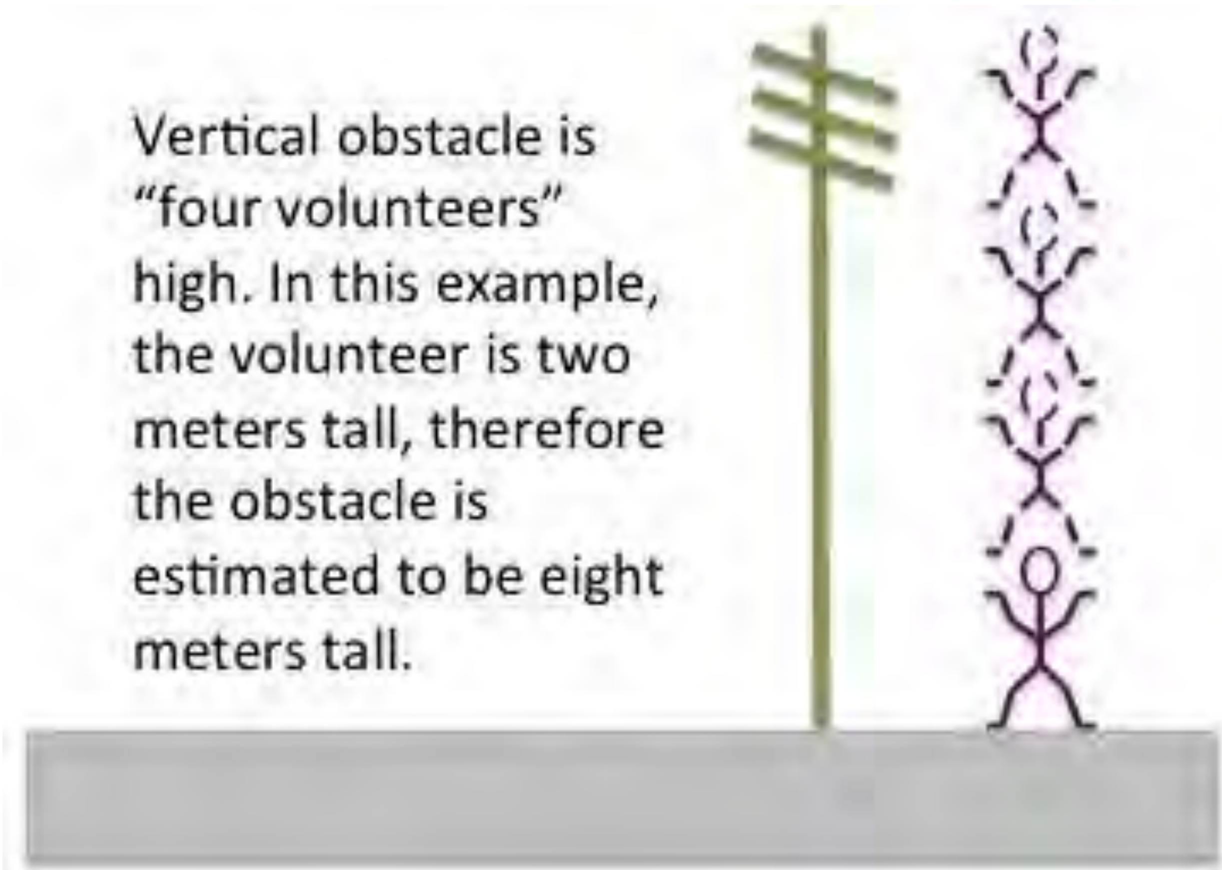


Figure 17 Vertical Obstacle Height Estimation Technique

3.3.4. Horizontal Dimension Estimation Techniques

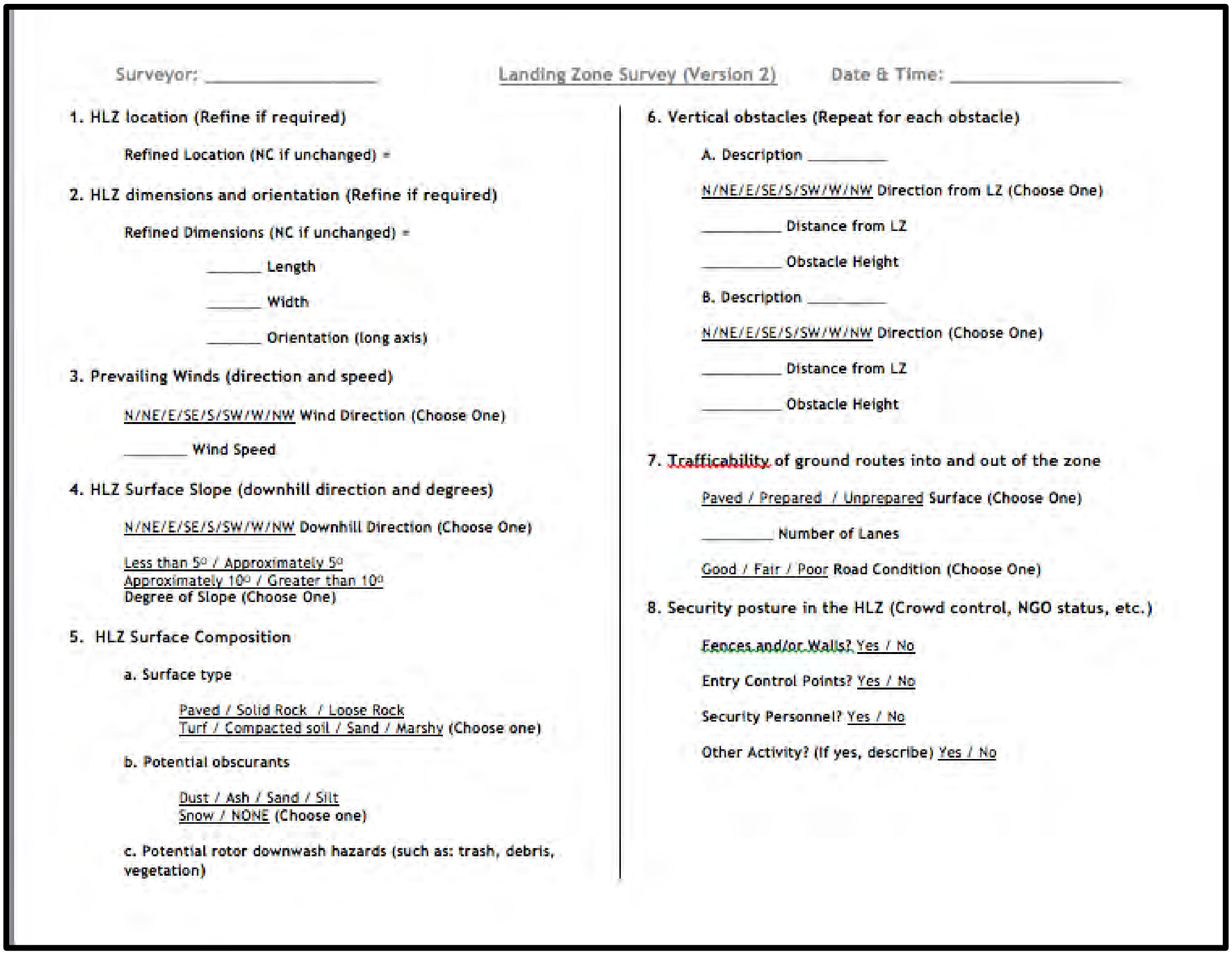
Volunteers may measure horizontal dimensions through employment of a pace count. During training, each volunteer will walk a measured distance using their natural gait, and noting the number of paces required to cover that distance. Surveyors calculate distances and horizontal dimensions using their respective pace count and simple arithmetic.

3.3.5. Visual Observation Survey Techniques of HLZs

Volunteers conducting visual observations possibly risk injecting bias and subjectivity into their HLZ surveys. This bias stems from many factors, to include cultural background, education, and training. Support materials and training for volunteer surveyors must encourage objective observations, and minimize unconscious bias.

3.3.6. HLZ Survey Documentation

A single-sheet survey form captured all of these HLZ components in an easy to use format. This form supported survey completion with a minimum of free text writing; fill-in-the-blank and multiple-choice menus were used where applicable. The use of standardized terms in these menus minimized the contamination of the surveys by observer bias. Figure 18 below depicts the initial Survey Form fielded to the volunteers. The researcher updated this form following volunteer feedback after the initial HLZ surveys.



Surveyor: ________________ Landing Zone Survey (Version 2) Date & Time: ________________

1. HLZ location (Refine if required)

   Refined Location (NC if unchanged) =

2. HLZ dimensions and orientation (Refine if required)

   Refined Dimensions (NC if unchanged) =

   ______ Length

   ______ Width

   ______ Orientation (long axis)

3. Prevailing Winds (direction and speed)

   N/NE/E/SE/S/SW/W/NW Wind Direction (Choose One)

   ______ Wind Speed

4. HLZ Surface Slope (downhill direction and degrees)

   N/NE/E/SE/S/SW/W/NW Downhill Direction (Choose One)

   Less than 5º / Approximately 5º
   Approximately 10º / Greater than 10º
   Degree of Slope (Choose One)

5. HLZ Surface Composition

   a. Surface type

   Paved / Solid Rock / Loose Rock
   Turf / Compacted soil / Sand / Marshy (Choose one)

   b. Potential obscurants

   Dust / Ash / Sand / Silt
   Snow / NONE (Choose one)

   c. Potential rotor downwash hazards (such as: trash, debris, vegetation)

6. Vertical obstacles (Repeat for each obstacle)

   A. Description ________

   N/NE/E/SE/S/SW/W/NW Direction from LZ (Choose One)

   ________ Distance from LZ

   ________ Obstacle Height

   B. Description ________

   N/NE/E/SE/S/SW/W/NW Direction (Choose One)

   ________ Distance from LZ

   ________ Obstacle Height

7. Trafficability of ground routes into and out of the zone

   Paved / Prepared / Unprepared Surface (Choose One)

   ________ Number of Lanes

   Good / Fair / Poor Road Condition (Choose One)

8. Security posture in the HLZ (Crowd control, NGO status, etc.)

   Fences and/or Walls? Yes / No

   Entry Control Points? Yes / No

   Security Personnel? Yes / No

   Other Activity? (If yes, describe) Yes / No

Figure 18 Initial HLZ Survey Form

3.3.7. Volunteer Training on HLZ Survey Techniques

The tools from Phase Three were taught to the members of the Hawaii County local community, who then used them to conduct detailed surveys of those HLZs that were the outputs of Phase One. Once these surveys are complete, the results will be submitted to the author, who would then input them to the OSM Web GIS. Feedback on the surveys and the associated training from the volunteer surveyors supported recursive updates of the survey forms, and improvements to the supporting training curriculum. Training focused on the survey process, not the volunteers. Feedback from the volunteers on the ease of comprehension and execution of the survey was collected, but only anonymously, with no consideration for the volunteers' race, gender, creed or age. Table 2 above contains the elements of the HLZ survey, and was submitted to the University Park Institutional Review Board, which yielded a finding that this interaction did not meet the criteria for Human Subjects Research.

Volunteers consisted of members of the local community from the northern part of Hawaii County. After initially trying and failing to secure the complete support of the Hawaii County Community Emergency Response Team (CERT), the researcher approached the staff at Hawaii Preparatory Academy (HPA) about securing volunteers from the student body as part of the school's community outreach program. The HPA staff determined that this project was being executed too late in that school's academic year to include it in the outreach program, but graciously agreed to share the request for assistance with the greater HPA community of staff and student families. This solicitation resulted in two families volunteering to assist with the research project, providing a total of seven volunteer surveyors. Both of these families asked if they could conduct their assigned surveys as a group effort, to which the researcher consented. The general demographics of the volunteer surveyors were as follows: (1) Three were adults, and four were teenagers, (2) Five were female and two were male. (3) Two of the adults were college graduates, with the remaining one a high school graduate. (4) The teenagers were one high school and three junior high school students. (5) None of the volunteers had a background in GIS, disaster response, or helicopter operations.

Volunteer training consisted of a combination of a Microsoft PowerPoint presentation of the techniques detailed above (Contained in Appendix C), coupled with a practical application exercise at a rugby field in Waimea. The PowerPoint presentation required approximately 45 minutes to teach, and the follow-on practical application required approximately 75 minutes. All of the instruction was conducted with the researcher serving as the sole instructor. Volunteers learned their individual pace counts by walking over a measured 100-foot distance and memorizing the number of paces required. Surveyors estimated the height of the rugby goalposts using the author (who stands six feet tall) as a unit of measure. Wind velocity calculations consisted of judging the wind direction relative to the sun position, and assessing the speed using the pointing method described above. Training on slope estimation occurred on the micro-slopes (which were likely emplaced to aid in drainage) on the periphery of the rugby field.

3.3.8. Survey Scenario Management

In order to exercise elements of the Volunteer HLZ Survey Workflow, the researcher implemented simulated conditions at two of the HLZs. At HLZ Peregrine in Waimea, the researcher told that the volunteers that primary HLZ was fouled by a gathering of simulated refugees, with the hope that the volunteers would recommend an adjacent site. During the HLZ surveys in Pahoa, the scenario provided to the surveyors indicated that a simulated hurricane had downed albizia trees across the roads leading up to HLZ Hummingbird. The researcher intended for this scenario injection to lead the surveyors to make a determination that the HLZ was untenable for HA/DR.

Chapter 4 Execution and Validation of Volunteer HLZ Surveys

Once planning and preparation for the volunteer HLZ surveys was completed, the focus of the research project shifted to execution of the ground-truth surveys and the subsequent validation of the results by professional helicopter aircrews. The volunteers conducted the surveys of the HLZs over a period of three days in mid-May 2017. Two discrete groups of professional helicopter aircrews validated the volunteer surveys during the month of July 2017. Figure 19 below depicts the Volunteer HLZ Workflow, with the elements covered in this chapter highlighted. Volunteers conduct ground-truth surveys of the potential HLZs, and the surveyors or their tasking agency uploads the results to OSM. Refined HLZ surveys are accessed on OSM by helicopter aircrews prior to HA/DR operations.

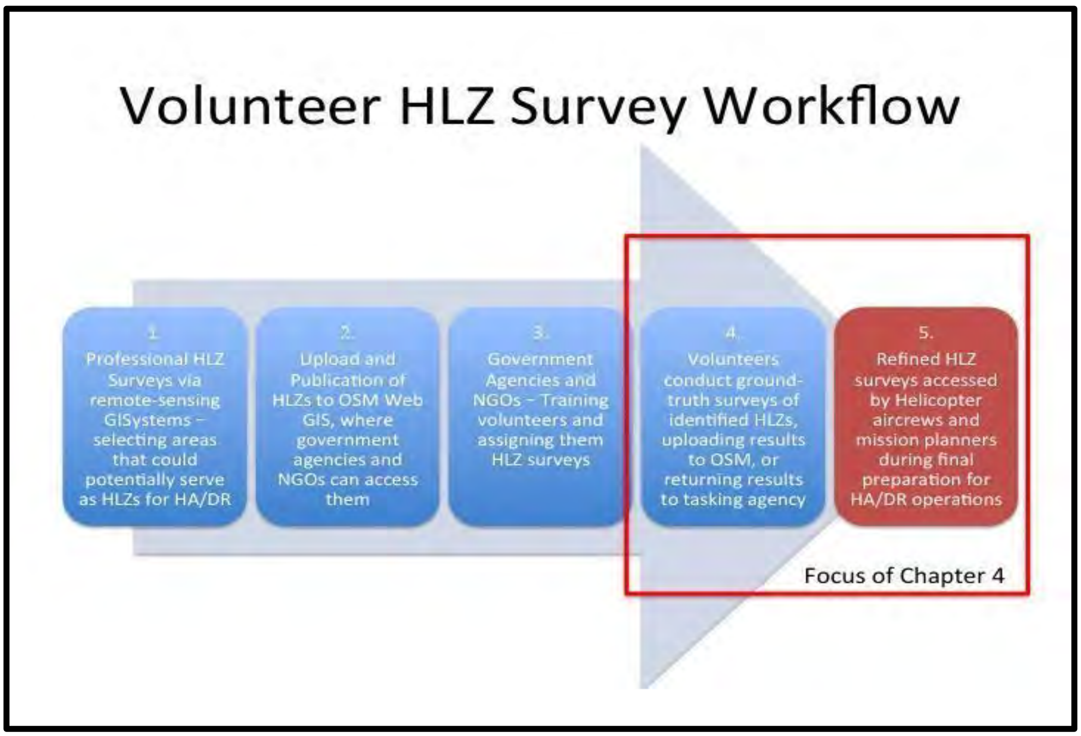


Figure 19 Volunteer HLZ Survey Workflow

4.1. Phase Four - Execution of Volunteer HLZ Surveys

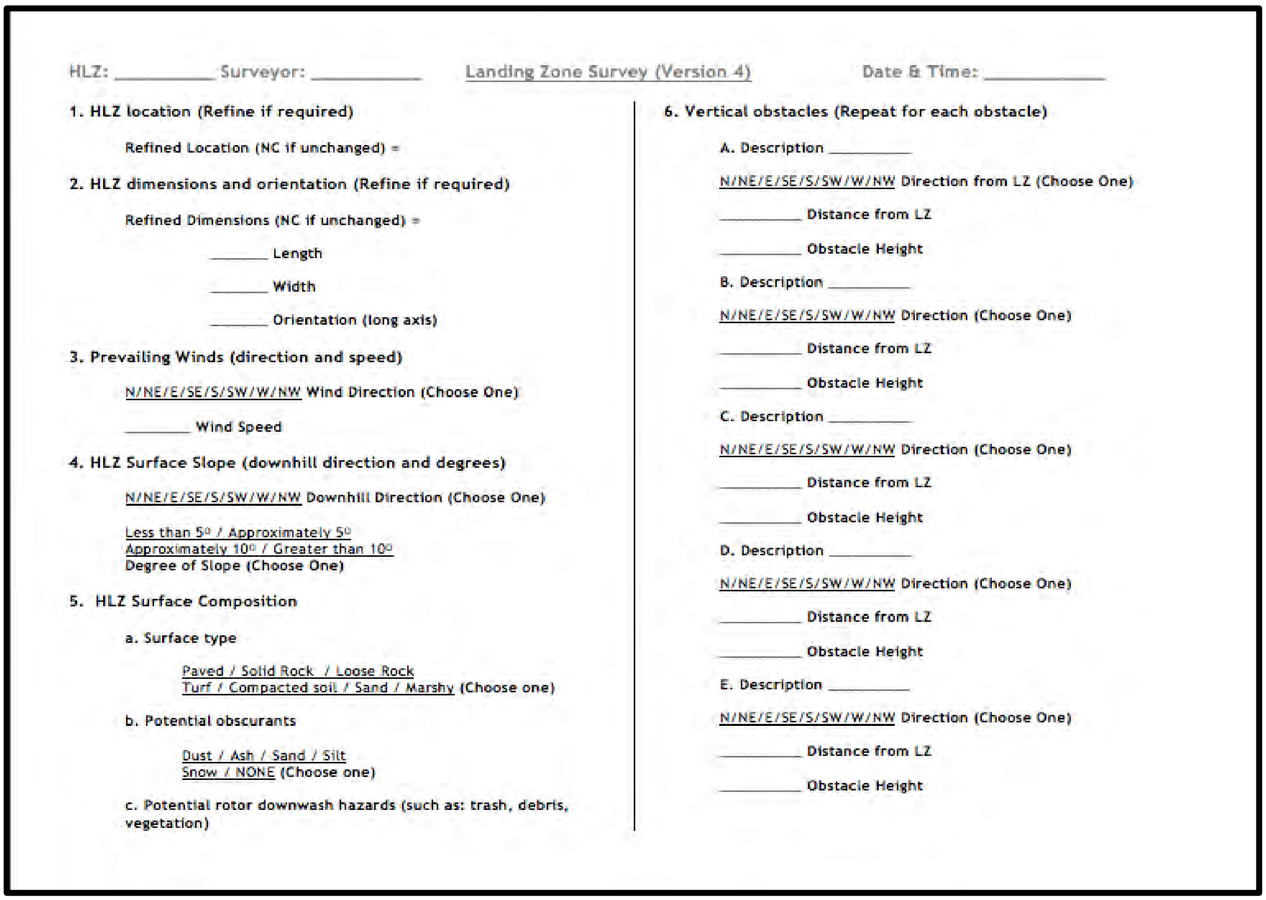
One team of four volunteers executed the surveys of the HLZs located in Waimea. The other team of three volunteers completed the surveys of the HLZs in Honokaa and Pahoa on two separate days. Enough time passed between the Waimea surveys and those in the other towns to allow volunteer feedback on the survey process to reach the researcher, and substantive changes to be made to the process before the subsequent surveys.

In order to induce the volunteers to exercise the skills taught during training, the researcher directed some minor simulations of conditions consistent with a disaster event. At HLZ Peregrine in Waimea, the researcher described a scenario to the volunteers where the primary HLZ site was occupied. At HLZ Hummingbird in Pahoa, the researcher provided a description of post-disaster conditions on the infrastructure adjacent a HLZ.

4.1.1. Surveys of Waimea HLZs

Volunteers surveyed three HLZs in Waimea. The HMLA planners selected locations at sports fields within the Waimea area as sites for these HLZs. The Parker School soccer fields hosted HLZ Owl. The town softball field contained HLZ Albatross. The final Waimea HLZ (Peregrine) rested on the baseball diamond on the campus of Hawaii Preparatory Academy (HPA). The researcher did not provide the volunteers with maps or imagery of the HLZs, instead relying on the volunteers' local knowledge of landmarks to navigate to the HLZ locations. Employment of this simplified technique accommodated the expectation that many volunteers would not be skilled at map-reading or remote-sensing imagery interpretations. At HLZ Peregrine, the researcher informed the volunteers that refugees establishing a tent village fouled the primary HLZ (as high school baseball diamond), thereby forcing the volunteers to determine an alternate location for the HLZ and conduct their survey at that site.

This team of volunteers provided feedback to the researcher on two aspects of the HLZ Survey Form: slope measurement techniques and the number of blanks available for vertical obstacles, resulting in the survey form being updated. A table for slope calculation (both macro and micro slopes) was included on the back of the form, and the number of blanks for documenting vertical obstacles was more than doubled. Figure 20 and Figure 21 below depict the resultant changes.



HLZ: __________ Surveyor: ___________ Landing Zone Survey (Version 4) Date & Time: ___________

1. HLZ location (Refine if required)

Refined Location (NC if unchanged) =

2. HLZ dimensions and orientation (Refine if required)

Refined Dimensions (NC if unchanged) =

_______ Length

_______ Width

_______ Orientation (long axis)

3. Prevailing Winds (direction and speed)

N/NE/E/SE/S/SW/W/NW Wind Direction (Choose One)

_______ Wind Speed

4. HLZ Surface Slope (downhill direction and degrees)

N/NE/E/SE/S/SW/W/NW Downhill Direction (Choose One)

Less than 5º / Approximately 5º
Approximately 10º / Greater than 10º
Degree of Slope (Choose One)

5. HLZ Surface Composition

a. Surface type

Paved / Solid Rock / Loose Rock
Turf / Compacted soil / Sand / Marshy (Choose one)

b. Potential obscurants

Dust / Ash / Sand / Silt
Snow / NONE (Choose one)

c. Potential rotor downwash hazards (such as: trash, debris, vegetation)

6. Vertical obstacles (Repeat for each obstacle)

A. Description _________

N/NE/E/SE/S/SW/W/NW Direction from LZ (Choose One)

_________ Distance from LZ

_________ Obstacle Height

B. Description _________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

_________ Distance from LZ

_________ Obstacle Height

C. Description _________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

_________ Distance from LZ

_________ Obstacle Height

D. Description _________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

_________ Distance from LZ

_________ Obstacle Height

E. Description _________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

_________ Distance from LZ

_________ Obstacle Height

Figure 20 Updated HLZ Survey Form (Front)

HLZ: ________ Surveyor: __________ Landing Zone Survey (Version 4) Date & Time: __________

7. Trafficability of ground routes into and out of the zone

   Paved / Prepared / Unprepared Surface (Choose One)

   _______ Number of Lanes

   Good / Fair / Poor Road Condition (Choose One)

8. Security posture in the HLZ (Crowd control, NGO status, etc.)

   Fences and/or Walls? Yes / No

   Entry Control Points? Yes / No

   Security Personnel? Yes / No

   Other Activity? (If yes, describe) Yes / No

9. General Notes:

Slope Calculator - Micro Terrain

Change in Elevation							
	5	>10°	>10°	>10°	>10°	>10°	5° > ∡ < 10°
	4	>10°	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°
	3	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°
	2	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	<5°	<5°
	1	>10°	5° > ∡ < 10°	<5°	<5°	<5°	<5°
Ratio based (Can be used for Metric or English Units, as long as units are applied uniformly (i.e., meters slant range must use meters elevation change, feet with feet))		5	10	15	20	25	30
		Slant Distance (base of slope to top)					

Slope Calculator – Macro Terrain

Change in Elevation									
	25	>10°	>10°	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°
	20	>10°	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°
	15	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°	<5°	<5°
	10	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	<5°	<5°	<5°	<5°
	5	>10°	5° > ∡ < 10°	<5°	<5°	<5°	<5°	<5°	<5°
Ratio based (Can be used for Metric or English Units, as long as units are applied uniformly (i.e., meters slant range must use meters elevation change, feet with feet))		25	50	75	100	125	150	175	200
		Slant Distance (base of slope to top)							

Figure 21 Updated HLZ Survey Form (Back)

4.1.1.1 Results of HLZ Owl Survey

The team of four volunteers estimated the height of vertical obstacles all around this HLZ with a greater degree of accuracy than had been achieved via JMPS. In particular, the trees along the southeastern perimeter were measured to be of heights varying from 50 to 120 feet tall. Volunteers employed the vertical obstacle measurement techniques from the survey training to determine that the electrical wires along the northwestern perimeter were approximately 60 feet tall.

As depicted in Figure 7, this HLZ possessed on major obstacle; a slope of greater than ten degrees. This slope was imperceptible on the remote-sensing imagery used in the JMPS HLZ Diagram, but was plainly evident to the volunteers during the survey. Terracing of the terrain to allow for two separate level soccer fields caused this significant but difficult to discern slope across the middle of the HLZ from southeast to northwest. The imagery in Figure 7, even when augmented with DTED, lacks the precision to depict a significant bit of micro-terrain bisecting the HLZ: a one and a half meter slope where the field was terraced to make a level playing surface for soccer. The micro-slope hazard presents a hazard, potentially forcing a helicopter into a dangerous sloped landing condition. Figure 22 presents the author standing at the base (left) and top (right) of the slope, with seven meters laterally separating the top and base.

Figure 22 HLZ Owl Microslope

4.1.1.2 Results of HLZ Albatross Survey

Volunteers found the survey of HLZ Albatross straightforward. No significant hazards existed in the HLZ itself. This team easily located and measured vertical hazards in the vicinity of the HLZ. Volunteers documenting these vertical hazards encountered difficulty while capturing data on the single page form, triggering the updates depicted in Figure 20 and Figure 21 above.

4.1.1.3 Results of HLZ Peregrine Survey

The HPA Campus hosts HLZ Peregrine on its baseball diamond. The researcher informed these volunteers that a tent village of refugees who have fled the dangerous conditions within Waimea occupied the baseball diamond. This scenario induced the volunteers to propose the adjacent football gridiron as an alternate site, upon which they based their survey. No significant hazards existed in the alternate HLZ itself. This team easily located and measured vertical hazards in the vicinity of the HLZ. Volunteers documenting these vertical hazards encountered difficulty while capturing data on the single page form, triggering the updates depicted in Figure 20 and Figure 21 above.

4.1.2 Surveys of Honokaa HLZs

Volunteers surveyed three HLZs in Honokaa. The HMLA planners selected two locations at sports fields within the Honokaa, and a third site at an open field adjacent the town clinic, as sites for these HLZs. The town park football field contained HLZ Parakeet. The Honokaa High School football field hosted HLZ Duck. The final Honokaa HLZ (Emu) rested in an open field upslope of the Hale Ho’ola Hamakua, the town clinic. Identically to the Waimea survey team, the researcher did not provide the volunteers with maps or imagery of the HLZs, instead relying on the volunteers’ local knowledge of landmarks to navigate to the HLZ locations. This team of three volunteers conducted their surveys while employing the updated survey form from Figure 20 and Figure 21 above.

4.1.2.1. Results of HLZ Parakeet Survey

Volunteers found the survey of HLZ Parakeet straightforward. Other than the football goalposts no significant hazards existed in the HLZ. The surface was a well-manicured football field with good drainage. This team easily located and measured vertical hazards in the vicinity of the HLZ. Of note, the volunteers estimated the height of the tree line along the southeastern perimeter of the HLZ to be over 200 feet above the HLZ surface, due to the fact that these trees were growing on a steep slope that loomed over the HLZ. Similarly, the rising terrain upon which they were emplaced amplified the heights of the light stanchions to the northwest of the HLZ. One hard surface road bordered the HLZ, providing good infrastructure support to HA/DR operations. Fences and entry control points supported a strong security posture at this HLZ.

4.1.2.2. Results of HLZ Duck Survey

Volunteers found HLZ Duck to be a suitable HLZ site, with the only noteworthy obstacles in the HLZ consisting of the two football goalposts (which could be easily knocked down in preparation for HA/DR helicopter operations). This team easily completed vertical obstacle measurements of hazards adjacent the HLZ using the trained techniques. The surface of the HLZ was hard-packed earth with turf. Two hard surface roads bordered the HLZ, providing good infrastructure support to HA/DR operations. Fences and entry control points supported a strong security posture at this HLZ.

4.1.2.3. Results of HLZ Emu Survey

This team of volunteers judged HLZ Emu to be untenable for HA/DR helicopter operations due to a number of factors. Volunteers estimated the slope of HLZ Emu to be greater that ten degrees downhill to the north. guinea grass (*megathyrsus maximus*) a very hearty invasive species of grass than grows in very dense tall clumps, covered the surface of the HLZ. The guinea grass in HLZ Emu had achieved a height of over eight feet in some areas, presenting a potential obscuration hazard for helicopter aircrews trying to locate a safe spot to land. Saplings of 10-15 foot height were interspersed with the guinea grass, presenting a potential hazard to the rotor systems of helicopters attempting to land.

4.1.3 Surveys of Pahoa HLZs

Volunteers surveyed three HLZs in Pahoa. The HMLA planners selected three open fields around this town as sites for these HLZs. The field across the road from the Pahoa Waste Transfer Station contained HLZ Macaw. HLZ Parrot is located 3500 meters east of the town, adjacent the Puna Geothermal Venture facility. The final Honokaa HLZ (Hummingbird) rested in an open field 1500 meters northeast of Pahoa. Identically to the Waimea survey team, the researcher did not provide the volunteers with maps or imagery of the HLZs, instead relying on the volunteers' local knowledge of landmarks to navigate to the HLZ locations. The researcher provided this team of three volunteers with a scenario whereby the narrow roads supporting access to HLZ Hummingbird were rendered untenable by numerous large albizia trees down across the roadbeds. Figure 23 depicts a map of these HLZs in the vicinity of Pahoa.

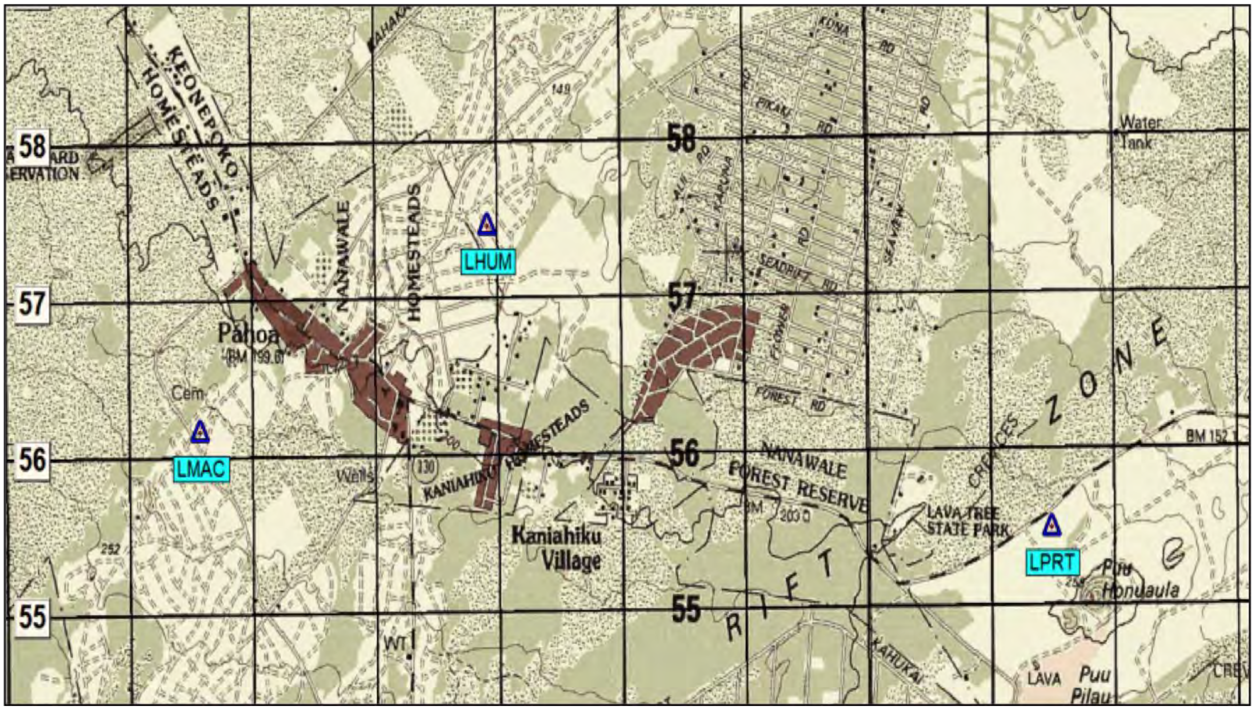


Figure 23 Pahoa HLZs

4.1.3.1. Results of HLZ Macaw Survey

HLZ Macaw occupies an open field southeast of the Pahoa Waste Transfer facility, and can be accessed from the same road that supports that facility. The 2015 lava flow from the Eastern Rift Zone of the Kiluaea volcano encroached on the entire northwestern side of the HLZ. The volunteers assessed this lava flow as untenable for helicopter landings as it varies from 10-20 feet high above the HLZ, with a very rough and uneven surface. Volunteers surveyed the remainder of the HLZ, discovering that the surface is soft, marshy ground covered with dense and entangling grass that is between two and six feet tall. The survey identified the supporting infrastructure as adequate with a prepared surface two-lane road in good condition located along the southwestern perimeter of the HLZ. A low barbed-wire fence provides some basic passive security measures at HLZ Macaw.

4.1.3.2. Results of HLZ Parrot Survey

Volunteers assessed the primary location for HLZ Parrot as untenable for helicopter operations due to very tall (eight to ten foot) guinea grass throughout the HLZ, interspersed with saplings of 10-15 foot height. This team located an alternate site on the west side of the road that bounded the HLZ to the east, adjacent the Puna Geothermal Venture. A survey of this site yielded an HLZ site of 200 by 200 feet, with a packed gravel surface. Slope at this slight was minimal, with small downslopes on all sides, likely to assist in drainage. This team easily completed vertical obstacle measurements of hazards adjacent the HLZ using the trained techniques.

4.1.3.3. Results of HLZ Hummingbird Survey

Volunteers found this HLZ untenable for HLZ operation for a number of reasons. This team found accessing this HLZ to be very challenging, as the only roads were unprepared, narrow, one-lane roads. All of these roads were bordered by large albezia trees, which were likely to be toppled in the high winds of a hurricane. The researcher introduced the disaster scenario of these trees being toppled across these roads, reducing access to the HLZ to almost nil. A cursory survey of the HLZ revealed that numerous shrubs and trees between six and twelve feet in height fouled it.

4.1.4 Collation and Upload of HLZ Survey Results

The teams of volunteers submitted completed surveys to the researcher, who then converted the data on the forms to text that could be easily uploaded to OSM. Table 4 below depicts the survey data in this format. The HLZs from Phase Two were opened for editing within

OSM, and their contents tagged with a “Description” and a “Note” field, which were used for presentation of the survey data. Survey data was uploaded in all capital letters to differentiate it from other HLZ data inputs. Figure 24 presents an example of the data once uploaded to OSM for HLZ Peregrine. Completion of editing allows the editor to copy the hyperlink to the HLZ. Table 4 contains survey results formatted for input to OSM. Table 5 depicts the OSM hyperlinks for the study HLZs.

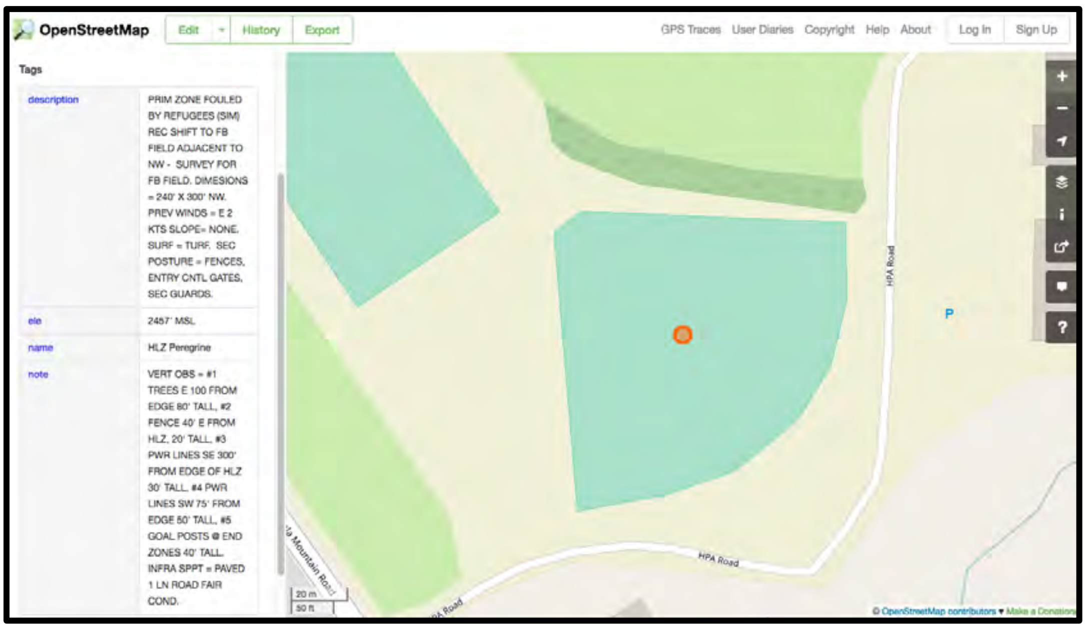


Figure 24 HLZ Peregrine Survey Results in OSM

Table 4 Collated HLZ Survey Results

HLZ Name	Location	Elevation	Dimensions	Description	Survey
OWL	20.0238739°, -155.6682637°	2694' MSL	150 X 100M	grass field with dirt patches, flat terrain. surrounded by trees and buildings. powerlines north of zone 2908' tower 1.5nm west	PREV WINDS = NE AT 11, SLOPE = 10 DEG TO SW - TERRACED BETWEEN SOCCER FIELDS (RUNS NW TO SE THRU MIDDLE OF LZ). SURF = TURF. VERT OBS = #1 TREES 50-75' SE OF EDGE OF HLZ 120' TALL, #2 TREES 200' E OF EDGE OF HLZ 50' TALL, #3 PWR LINES 250' N OF EDGE OF HLZ 60' TALL. INFRASTRUCTURE SPPT = 2 LANE PAVED RD IN FAIR CONDITION. SEC POSTURE = DENSE HEDGE ON PERIMETER, GATE AT DRIVEWAY, NO SEC PERS.
ALBATROSS	20.0230926°, -155.6721673°	2671' MSL	150 X 100M	grass field with dirt patches, flat terrain. surrounded by trees and buildings. Large stadium lights located to the southeast	PREV WINDS = NE AT 8 SLOPE = NONE. SURF = TURF. VERT OBS = #1 PWR LINES 40' S OF EDGE OF HLZ 60' TALL, #2 PWR LINES N 200' FROM HLZ 50' TALL, #3 TREES SW 50' FROM HLZ 50' TALL, #4 6 X STADIUM LTS 20-100' E-SE FROM EDGE OF HLZ 80' TALL. #5 FENCE 20' SW OF EDGE OF HLZ, 12' TALL. INFRASTRUCTURE SPPT = 2 LANE PAVED RD GOOD COND. SEC POSTURE = PERIMETER FENCE, ENTRY CONTROL GATES, NO SEC PERS.
PEREGRINE	20.0286515°, -155.6985331°	2457' MSL	100 X 100M	grass field (baseball diamond). surrounded by trees to the north south zone enclosed by a fence. north to south descending terrain.	PRIM ZONE FOULED BY REFUGEES (SIMULATED) REC SHIFT TO FB FIELD ADJACENT TO NW - SURVEY FOR FB FIELD. DIMESIONS = 240' X 300' NW. PREV WINDS = E 2 KTS SLOPE = NONE. SLOPE= NONE. SURF = TURF. VERT OBS = #1 TREES E 100 FROM EDGE 80' TALL, #2 FENCE 40' E FROM HLZ, 20' TALL, #3 PWR LINES SE 300' FROM EDGE OF HLZ 30' TALL, #4 PWR LINES SW 75' FROM EDGE 50' TALL, #5 GOAL POSTS AT END ZONES 40' TALL. INFRASTRUCTURE SPPT = PAVED 1 LN ROAD FAIR COND. SEC POSTURE = FENCES, ENTRY CNTL GATES, SEC GUARDS.
PARAKEET	20.0747413°, -155.4672826°	1181' MSL	100 X 75M	grass soccer field. rising slope in southwest corner. bordered by trees to south. large stadium lights to northwest of zone	PREV WINDS = CALM. SLOPE = NONE. SURF = TURF. VERT OBS = #1 GOAL POSTS END ZONES 25' TALL, #2 LT POST 125' NW OF EDGE OF HLZ 30' TALL, #3 LT POST 125' W OF EDGE OF HLZ 30' TALL, #4 TREES E 125' FROM HLZ, 35' TALL, #5 TREES UPSLOPE 225' E OF HLZ, 200' ABOVE HLZ. INFRASTRUCTURE SPPT = PAVED 2 LN RD GOOD COND. SEC POSTURE = FENCES, ENTRY CNTL GATES.
DUCK	20.0763348°, -155.4631022°	1145' MSL	100 X 75M	grass football field. south to north descending terrain. Football goal posts located on east and west ends of zone. large stadium lights surrounding zone	PREV WINDS = E 5 KTS. SLOPE = NONE. SURF = TURF.VERT OBS = #1 GOAL POSTS END ZONES 25 FT, #2 STADIUM LTS 30' FROM N&S EDGES OF HLZ, 60' TALL. INFRASTRUCTURE SPPT = PAVED 2 LN RD GOOD COND. SEC POSTURE = FENCES, ENTRY CNTL GATES.
EMU	20.0737984°, -155.4701351°	1276' MSL	200 X 100M	grass field with dirt patches. south to north descending terrain. trees to the west of zone. large slope from south to north	APPEARS UNTENABLE DUE TO SLOPE. PREV WINDS = E 5 KTS. SLOPE > 10 DEG DOWN TO S. SURF = TURF & MARSHY SOIL. VERT OBS = #1 12' TREES THROUGHOUT HLZ, #2 GUINEA GRASS 6-8' TALL THROUGHOUT HLZ, #3 PWR LINES 100' N HLZ, 75' TALL.
HUMMINGBIRD	19.5015554°, -154.9349924°	571' MSL	575 X 450M	scrubgrass with isolated trees. upslope northeast to southwest	APPEARS NOT VIABLE DUE TO NO ACCESS RD INFRASTRUCTURE. RDS NARROW & POTENTIALLY BLOCKED BY FALLEN ALBIZIA TREES. HLZ FOULED BY 6-8' SHRUBS AND 10-12' TREES.
MACAW	19.4895732°, -154.9572340°	735' MSL	980 X 350M	scrubgrass and lava rock, upslope northeast to southwest 50 foot trees around zone, road in the middle of zone	PREV WINDS = E 5KTS. SLOPE = 5 DEG DOWN TO NE. SURF = MARSHY WITH DENSE 2' GRASS. VERT OBS = #1 PWR LINES SW BOUNDARY OF HLZ 75' TALL, #2 LAVA FLOW NW EDGE OF HLZ 10-20' TALL AND UNEVEN. INFRASTRUCTURE SPPT = PAVED 2 LN RD FAIR COND. SEC POSTURE = FENCES.
PARROT	19.4842222°, -154.8912574°	614' MSL	800 X 900M	powerlines north of zone. tower to north of zone trees border zone on west. shrubs in zone	PRIMARY HLZ UNTENABLE DUE TO 8-10' TALL VEGETATION. ALT HLZ ON EAST SIDE OF FIELD, NEAR PUNA GEOTHERMAL PLANT. SURVEY FOR ALT HLZ. 200 X 200' CLEARING JUST WEST OF MSR. PREV WIDS = E 5 KTS SLOPE = 5-10 DEG AROUND PERIMETER OF GRAVEL HLZ. VERT OBS = #1 PWR LINE 75' E OF HLZ 50' TALL, #2 METAL ANTENNA SE 1000' FROM LZ 100' TALL, #3 TREES 500' N OF HLZ, 50-75' TALL INFRASTRUCTURE = 2 LN RD FAIR COND. SEC POSTURE = NONE.

Table 5 OSM HLZ Hyperlinks

HLZ Peregrine (4957422889, v5) https://www.openstreetmap.org/node/4957422889
HLZ Albatross (4957431870, v4) https://www.openstreetmap.org/node/4957431870
HLZ Owl (4493721867, v6) https://www.openstreetmap.org/node/4493721867
HLZ Emu (4957486155, v3) https://www.openstreetmap.org/node/4957486155
HLZ Parakeet (4957486153, v3) https://www.openstreetmap.org/node/4957486153
HLZ Duck (4957486154, v3) https://www.openstreetmap.org/node/4957486154
HLZ Macaw (4957528281, v3) https://www.openstreetmap.org/node/4957528281
HLZ Parrot (4957696107, v3) https://www.openstreetmap.org/node/4957696107
HLZ Hummingbird (4957528280, v3) https://www.openstreetmap.org/node/4957528280

4.2. Phase Five – Survey Results Validation

Phase Five focused on the validation of the outputs of Phase Four. Helicopter aircrews from HMLA-367 and from the community of helicopter pilots in Hawaii County were provided the original JMPS HLZ diagrams, and the hyperlinks from OSM as depicted in Table 5, and asked to provide feedback. They were asked to compare their work products from Phase One (JMPS diagrams) with the outputs of Phase Four (Survey results contained in OSM), all from the perspective of aircrews that could be asked to operate in the HLZs. Anecdotal evidence was collected from these observations, and serve as validation of the volunteer surveys. These professional helicopter planners assessed the volunteer surveys by the eight HLZ Survey functional areas as defined in the Survey Form depicted in Figure 25 and Figure 26. These HLZ criteria consist of: (1) HLZ location, (2) HLZ dimensions and orientation, (3) Prevailing winds, (4) Surface slope, (5) Surface composition, (6) Vertical obstacles, (7) Trafficability of routes to the HLZ, and (8) HLZ security posture. General feedback from the aircrews revealed that the crowdsourced data was value added to their planning for operations in the HLZs. Almost unanimously, the five helicopter pilots wanted some means to communicate with the surveyors to ask clarifying and amplifying questions about the survey results.

HLZ: ________ Surveyor: __________ Landing Zone Survey (Version 4) Date & Time: __________

1. HLZ location (Refine if required)

Refined Location (NC if unchanged) =

2. HLZ dimensions and orientation (Refine if required)

Refined Dimensions (NC if unchanged) =

_____ Length

_____ Width

_____ Orientation (long axis)

3. Prevailing Winds (direction and speed)

N/NE/E/SE/S/SW/W/NW Wind Direction (Choose One)

______ Wind Speed

4. HLZ Surface Slope (downhill direction and degrees)

N/NE/E/SE/S/SW/W/NW Downhill Direction (Choose One)

Less than 5º / Approximately 5º
Approximately 10º / Greater than 10º
Degree of Slope (Choose One)

5. HLZ Surface Composition

a. Surface type

Paved / Solid Rock / Loose Rock
Turf / Compacted soil / Sand / Marshy (Choose one)

b. Potential obscurants

Dust / Ash / Sand / Silt
Snow / NONE (Choose one)

c. Potential rotor downwash hazards (such as: trash, debris, vegetation)

6. Vertical obstacles (Repeat for each obstacle)

A. Description ________

N/NE/E/SE/S/SW/W/NW Direction from LZ (Choose One)

________ Distance from LZ

________ Obstacle Height

B. Description ________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

________ Distance from LZ

________ Obstacle Height

C. Description ________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

________ Distance from LZ

________ Obstacle Height

D. Description ________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

________ Distance from LZ

________ Obstacle Height

E. Description ________

N/NE/E/SE/S/SW/W/NW Direction (Choose One)

________ Distance from LZ

________ Obstacle Height

Figure 25 Updated HLZ Survey Form (Front)

HLZ: ________ Surveyor: __________ Landing Zone Survey (Version 4) Date & Time: ___________

7. Trafficability of ground routes into and out of the zone

Paved / Prepared / Unprepared Surface (Choose One)

________ Number of Lanes

Good / Fair / Poor Road Condition (Choose One)

8. Security posture in the HLZ (Crowd control, NGO status, etc.)

Fences and/or Walls? Yes / No

Entry Control Points? Yes / No

Security Personnel? Yes / No

Other Activity? (If yes, describe) Yes / No

9. General Notes:

Slope Calculator - Micro Terrain

Change in Elevation							
	5	>10°	>10°	>10°	>10°	>10°	5° > ∡ < 10°
	4	>10°	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°
	3	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°
	2	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	<5°	<5°
	1	>10°	5° > ∡ < 10°	<5°	<5°	<5°	<5°
Ratio based (Can be used for Metric or English Units, as long as units are applied uniformly (i.e., meters slant range must use meters elevation change, feet with feet))		5	10	15	20	25	30
		Slant Distance (base of slope to top)					

Slope Calculator - Macro Terrain

Change in Elevation									
	25	>10°	>10°	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°
	20	>10°	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°
	15	>10°	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	5° > ∡ < 10°	<5°	<5°
	10	>10°	>10°	5° > ∡ < 10°	5° > ∡ < 10°	<5°	<5°	<5°	<5°
	5	>10°	5° > ∡ < 10°	<5°	<5°	<5°	<5°	<5°	<5°
Ratio based (Can be used for Metric or English Units, as long as units are applied uniformly (i.e., meters slant range must use meters elevation change, feet with feet))		25	50	75	100	125	150	175	200
		Slant Distance (base of slope to top)							

Figure 26 Updated HLZ Survey Form (Back)

4.2.1. Validation of HLZ Location

With two exceptions, the volunteer surveyors did not shift locations of the HLZs from their initial position as defined in the JMPS diagrams. In the first instance, the volunteer surveyors were informed that HLZ Peregrine, the baseball diamond on the campus of HPA, was fouled by refugees, driving them to recommend relocation of the HLZ to the adjacent football gridiron. This shift was easily depicted through a written description of the direction and distance of this shift, and the description of the new HLZ as a football gridiron. The helicopter aircrews found this shift easy to comprehend and visualize, especially when this description was paired with the original HLZ diagram.

In the second instance where the volunteer surveyors recommended a new location for the HLZ, the helicopter aircrews found the results to be less useful. HLZ Parrot was located east of Pahoa, in a large field that appears from the remote sensing imagery to be a level, grassy surface. Ground truth surveying revealed that tall vegetation and shrubs fouled the initial location. The volunteer surveyors located a cleared area to the east of the original HLZ, and described its location relative to the Puna Geothermal Venture, a local facility marked by prominent signage. As this signage was not visible on the remote-sensing imagery, and the majority of the helicopter aircrews were not familiar with this landmark, the location of the proposed new HLZ seemed unclear. Some means of updating the location of the HLZ in OSM, in a standard coordinate format, was desired by the aircrews.

Surveyors identified a significant micro-slope that essentially bisected the HLZ Owl into two discrete HLZs. The word description of this sloped obstacle lacked clarity as to its location in the HLZ, even as its slope was estimated by the volunteers. Helicopter aircrews stated that some means of deriving coordinates or a graphic depiction of this hazard would be desirable.

4.2.2. Validation of HLZ Dimensions

The helicopter aircrews found that the volunteer surveyor estimates of HLZ dimensions to be generally additive to their knowledge of the HLZ. While the dimensions could usually be assessed on the remote-sensing imagery in JMPS as detailed in Chapter 3, confirmation from the volunteers was viewed positively. In those instances where the dimensions of the HLZ had been affected by an obstacle undetectable on the remote-sensing imagery, as in the case of the micro slope in HLZ Owl in Waimea, or altered by some disaster mechanism, as in the case of the lava flow in the northwest portion of HLZ Macaw in Pahoa, the surveyors estimates of the remaining usable dimensions of the HLZ would prove invaluable.

4.2.3. Validation of HLZ Prevailing Winds

Prevailing winds estimates by the volunteer surveyors received positive feedback from the helicopter aircrews. The aircrews did ask that for details as to the date and time that these wind velocity estimates were executed, as time of day and regional weather activity may impact these assessments. Conduct of prevailing winds assessments in an HLZ over time and up until the time of helicopter operations would provide valuable data to the helicopter aircrews, as weather observations from sites away from the HLZ and hours before cannot account for the effects on wind velocity of buildings, terrain, and local conditions in the immediate vicinity of the HLZ.

4.2.4. Validation of HLZ Surface Slope

Of all of the elements of the crowd-sourced HLZ surveys, the helicopter aircrews placed the greatest value on the volunteer surveyors' slope estimations. The helicopter crews universally praised the determination that HLZ Emu in Honokaa possessed a surface slope greater than 10 degrees, as that HLZ would be of limited use for HA/DR operations. The survey proved that he capabilities of complex GIS like JMPS are only as good as the imagery and data fed to them.

The presence of the 'hidden' micro-slope bisecting HLZ Owl in Waimea captured the interest of all of the aircrews, as the HLZ appears very benign from the JMPS remote-sensing imagery, which might well have led to complacency on the part of crews during landing. The estimated severity of the slope in this HLZ would not support the safe landing of some helicopters, and the aircrews wanted more information as to that hazards exact location.

4.2.5. Validation of HLZ Surface Composition

The helicopter aircrews pointed out that this HLZ characteristic benefited greatly from the efforts of the volunteer surveyors. Crowd-sourced data regarding the soft, heavily vegetated surface of HLZ Emu in Honokaa, when coupled with surface slope estimations for that location, served as very good inputs to the decision by the helicopter aircrews to not use that HLZ (Cruz 2017). The surveys of HLZ Macaw in Pahoa, which revealed the significant lava flow and dense deep vegetation on its surface, provided the helicopter aircrews with data essential to determining viability of the HLZ. The crews that developed the JMPS HLZ diagrams for this HLZ expressed surprise at the surface composition of this location, as the remote-sensing imagery adequately depicted the vertical dimensions and rough surface of the lava flow there.

4.2.6. Validation of HLZ Vertical Obstacles

Helicopter aircrews expressed great satisfaction with the volunteer surveyor efforts in this HLZ survey functional area. Measurement of vertical obstacle heights in JMPS remains inexact. Ground truth surveys of vertical hazards by volunteers in the vicinity of the HLZs closer to built up areas, as in Honokaa and Waimea, received near universal praise from the helicopter aircrews. One helicopter pilot requested additional vertical obstacle data for the buildings on the approach and retirement routes for the HLZs in Waimea and Honokaa.

4.2.7. Validation of Trafficability of Surface Routes to/from the HLZ

The helicopter aircrews assessed this functional area of the surveys, as executed within this study, to be of limited value. The survey of HLZ Hummingbird in Pahoa determined that the roads serving this HLZ were in very poor condition, and crowded by hazardous albizia trees, several of which were simulated to have been felled by high winds of a natural disaster, all of which the aircrews saw as valuable information. As the balance of the HLZ surveys reflected roads in good condition, the helicopter aircrews had little opportunity to provide a detailed assessment of the volunteer collected data. One pilot did envision how this data could prove invaluable in a real HA/DR situation, where disaster mechanisms have wreaked havoc on surface infrastructure.

4.2.8. Validation of HLZ Security Posture

Much like the route trafficability functional area, survey notes of the security posture at the HLZs were viewed to be of limited utility. The helicopter aircrews understood the shortfalls of the survey results in this functional area derived from the artificial nature of the study scenario. The absence of active security measures limited the surveys to data about passive security measures such as fences and gates.

Chapter 5 Conclusions and Recommended Future Work

The conclusions and recommended future work stemming from this research project shall be examined through the lens of the requirements of the target audience. The audience for this research project consists of three groups: government agencies and NGOs conducting HA/DR, volunteers surveying HLZs, and helicopter aircrews supporting HA/DR operations. The government agencies and NGOs coordinating the overall HA/DR effort require the logistical support to assistance and recovery be executed in the most efficient and effective means possible. The people who choose to volunteer their efforts to support the HA/DR by crowdsourcing HLZ surveys require survey techniques and procedures that foster both straightforward comprehension and easy execution. The helicopter crews supporting the HA/DR operations require detailed geospatial data about potential HLZs that enhance safe and efficient employment of these HLZs. Additionally, in support of the efforts of future researchers, Figure 27 depicts a timeline for the execution of the major elements of this Masters Thesis.

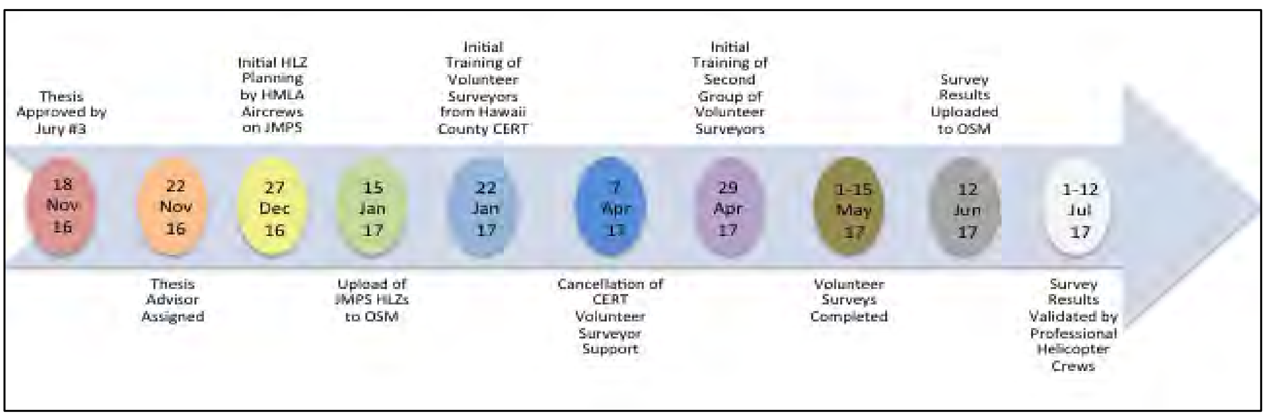


Figure 27 Thesis Timeline

In general, the results of this study highlighted some shortfalls in the project scenario that bear some analysis and discussion. More specifically, the government agencies and the NGOs generated a mixed response to this research project, with the negative aspects stemming from a perceived passive reluctance on the part of the government agencies that were part of this study to place much emphasis on volunteer support for disaster response. NGOs, specifically the HOT, seek assistance in developing a technical and procedural roadmap for implementation of this geospatial workflow. Feedback from the volunteer HLZ surveyors indicated that room exists for improvement and expansion of the training package and the data input and dissemination processes. The helicopter aircrews exhibited great enthusiasm for this initiative, but seek some means of interactive communication with the surveyors during the planning process and up to the point of mission execution, as well as more of the survey results presented to them in a graphic, vice text, format. This study also highlighted potential areas for concern with regards to operational security of the mission specific geospatial data, where bad actors or well-intentioned incompetence could compromise critical data, potentially with serious consequences for the helicopters and agencies involved. Analysis of these conclusions shall generate requirements for recommended future work, which shall be introduced in the latter half of this chapter.

5.1 Analysis and Conclusions

In hindsight, the scenario developed for this research project lacked some elements for fully exercising the Volunteer HLZ Survey Workflow. Additionally, employment of a volunteer workforce for the surveys presented challenges for timely completion of the research project, while highlighting a broader problem regarding volunteer support to HA/DR operations.

Analysis of the HOT involvement revealed areas for improvement of the workflow. Some improvements of the volunteer surveyor training process were executed in-stride based of feedback from the volunteers whilst in training, but the study also revealed that the training could be expanded to incorporate readily-available technologies to assist in the survey process. Analysis of the volunteer surveyors' submission of their results revealed areas for improvement of the workflow. The validation process highlighted the demand for interactive communication between the surveyors and the helicopter aircrews when elements of the survey results needed greater emphasis or clarification. Additionally during the validation process, the helicopter aircrews found crucial elements of the survey results inadequately presented via text, and sought solutions that yielded a graphic presentation of those features. Lastly, operational security presents challenges to all aspects of military operations, even in a seemingly benign mission set as HA/DR, and analysis of the volunteer HLZ survey workflow must account for these challenges.

5.1.1. Study Scenario Shortfalls

Limitations of time and resources prevented the development of a scenario that fully tested all aspects of the volunteer HLZ survey workflow. Other than the 2015 lava flow through HLZ Macaw in Pahoa, no actual disaster conditions existed within the study area during the execution of this research project. In order to challenge the surveyors' execution of the HLZ location and HLZ dimensions functional areas, the researcher simulated that a large group of refugees occupied the primary location of HLZ Peregrine. Additionally, the researcher simulated downing of the albizia trees along the approach and retirement routes to HLZ Hummingbird in

Pahoa, in order to stimulate the surveyors to exercise the trafficability functional area. While both of these scenario conditions triggered meaningful inputs by the surveyors and positive validation by the helicopter aircrews, conditions that would support other functional areas of the survey were not present, nor could they be simulated in a realistic fashion. Security posture at all of the study area HLZs consisted of passive measures such as fences and gates. Simulating active security measures such as guards or police and manned entry control points would require role players.

A live HA/DR exercise with role players or actual security forces provides the best environment short of an actual disaster event to completely evaluate the Volunteer HLZ Survey Workflow. This HA/DR exercise must include a Master Scenario Events List (MSEL) tailored to all of the functional areas of the workflow. This MSEL must be managed and documented to ensure that the various elements of the workflow receive a rigorous evaluation, and any deficiencies are documented, along with recommended corrections.

5.1.2. Volunteers in the HA/DR Environment

This research project suffered an extensive delay after the training of the initial group of volunteer surveyors from the Community Emergency Response Team (CERT) of Hawaii County. Attempting to schedule these trained volunteers for HLZ surveys failed, with no explanation readily apparent to the researcher. Discussion of these circumstances with people familiar with Hawaii County politics linked this obstacle to progress to the election of a new county mayor. This politician supervised the county Civil Defense office for a number of years before running for mayor, and consistently displayed a combination of disdain and wariness towards the efforts of volunteers attempting assist government agencies during HA/DR operations. Anecdotal evidence suggested to the researcher that the County Civil Defense office discouraged CERT personnel from supporting this study. Government officials around the world may possess these same prejudices against the efforts of volunteers. Volunteers possess inherent immunity from government supervision (they cannot be fired), and the level and consistency of volunteer competence resists easy quantification.

Continued documented refinement of the volunteer HLZ survey workflow, coupled with its successful implementation during HA/DR exercises and actual HA/DR operations may break down bureaucratic hostility towards volunteer efforts in support of HLZ surveys for HA/DR. Established NGOs and volunteer-based agencies, such as OSM, adopting this workflow may ease concerns from HA/DR coordinators. Military helicopter units gaining exposure to the efficacy of the workflow in HA/DR exercises, and subsequently providing an enthusiastic endorsement of its utility may assist in improving the likelihood of its widespread adoption.

5.1.3. NGOs and the Volunteer HLZ Survey Workflow

During the execution of this project, the researcher simulated many of the interfaces between the surveyors and the HOT, and the helicopter aircrews and the HOT. The researcher manually converted and uploaded to OSM details about the HLZs derived from the JMPS HLZ diagrams. Similarly, the researcher manually uploaded to OSM details about the HLZs from the volunteer surveys. In both instances, the researcher employed the Point feature and its available fields to capture and display pertinent HLZ data. In the absence of specific fields corresponding to the eight functional areas of the HLZ survey geospatial workflow, the Description and Notes fields were used to capture and display the HLZ data. These fields supported free text entry only, and that only to a total of 250 characters.

The researcher shall provide the HOT details of the key elements required in a dedicated HLZ feature for inclusion on the HOT Web GIS application. This HLZ feature must contain fields that support the elements of the Volunteer HLZ Survey Workflow, utilizing drop down menus where appropriate, and containing text fields large enough to contain pertinent data. The researcher shall closely coordinate with the HOT in the development of this new HLZ feature.

5.1.4. The HLZ Surveyor Training Process

Training as executed in this research project provided the volunteers with adequate baseline knowledge of HLZ survey techniques. The PowerPoint-based training syllabus contained in Appendix A focused on the fundamental processes for surveying HLZs using no specialized tools or high technology applications. Expansion of the training syllabus must support the integration of these additional capabilities, while still remaining effective for training volunteers in low- or no-technology environments.

Volunteers with access to mobile computing technologies that support slope and/or vertical hazard measurements require additional training on how those applications might support HLZ surveys. Development of a supplement to the basic syllabus must address integration of advanced technologies into the workflow by more sophisticated volunteer surveyors. Adaptation of the training syllabus to utilize advanced teaching technologies (i.e., video, interactive systems) shall be explored.

5.1.5 Volunteer Interaction with the HLZ Survey Workflow

Much like the training syllabus must be scalable to the available technologies and the aptitude of the volunteers, the Volunteer HLZ Survey Workflow must accommodate volunteers that possess advanced abilities and technologies. Volunteers with access to mobile computing technologies might possess the ability to directly access OSM from the HLZ, directly uploading survey results. Inclusion of these high-tech options in the workflow must not occur at the expense of technologically disadvantaged volunteer surveyors. In concert with the development of the new HLZ feature in the HOT Web GIS as detailed in paragraph 5.1.3 above, the researcher shall coordinate with the HOT to ensure that the updated workflow supports sophisticated super users, but not to the detriment of efforts by basic volunteer surveyors.

5.1.6. Interaction between Helicopter Planners and Volunteer Surveyors

Both the volunteer surveyors and the helicopter aircrews expressed the desire to have means for interactive direct communication with each other during the survey process. Surveyors might require clarification from helicopter mission planners as to specific details on the proposed HLZ. Conversely, the helicopter aircrews might need to query surveyors on specific data recorded during the survey, as was the case with the survey of HLZ Parrot in Pahoa. Aircrews were unclear as to where relative to the original zone the proposed HLZ was located. A process for submitting and answering requests for information between surveyors and aircrews would facilitate more effective information transfer in support of the workflow. In concert with the development of the new HLZ feature in the HOT Web GIS as detailed in paragraph 5.1.3 above, the researcher shall coordinate with the HOT to ensure that the updated workflow supports interaction between surveyors and the aircrews, where the surveyors might span a broad spectrum of sophistication and capabilities.

5.1.7. Conversion of Survey Data to Graphic Format

The helicopter aircrews stated that certain key features of the HLZ survey results required depiction via a graphic format vice a word picture. In the case of the micro slope hazard the surveyors located in HLZ Owl in Waimea, the text description as to the location of this obstacle was judged inadequate by the helicopter aircrews. Modification of the workflow to support a HOT super-user or editor creating a graphic overlay of key elements of the HLZ survey would enhance survey effectiveness. Modifications to the mobile OSM application would support those surveyors possessing mobile computing technology directly creating and uploading graphic features corresponding to critical features of HLZ surveys. In concert with the development of the new HLZ feature in the HOT Web GIS as detailed in paragraph 5.1.3 above, the researcher shall coordinate with the HOT to ensure that the updated workflow includes the ability to create, annotate, edit, and promulgate critical results of the workflow results.

5.1.8. Operational Security and the HLZ Surveys

Not all parties present in the environment of a HA/DR operation want the relief effort to succeed. Hostile political entities and organized crime organizations might wish to exploit the instability of a disaster to further their own objectives. The open nature of OSM presents an operational security challenge to the helicopter providing organizations participating in the Volunteer HLZ Survey Workflow. Bad actors might delete or alter the HLZ survey information in OSM, at a minimum reducing the efficiency of helicopter support operations, or destroying relief helicopters in a worst-case scenario. Movement of digital geospatial data (in the form of the volunteer HLZ surveys) from OSM to closed-loop military information systems might serve as a vector for malicious code during cyber attacks. Operational security must be addressed early in the initiation of the Volunteer HLZ Survey Workflow, and continuously throughout its execution.

Standards for operational security vary from organization to agency. The researcher shall support the various agencies in their adaptation of the workflow to their particular operational security requirements. Compliance with the operational security requirements might reduce the efficacy of the workflow. Adjustments of the workflow to maintain the timely and effective transmission of HLZ survey data may be necessary after addressing operational security concerns.

5.2. Future Work

This proposed workflow must transition from its academic roots to practical application during real-world HA/DR operations. Close coordination with the HOT to refine the workflow must include exploitation of the HOT's close working relationships with various disaster response NGOs. The HOT could persuade these entities adapt the workflow to support their employment of helicopter support during HA/DR.

The nascent workflow would benefit from inclusion in live HA/DR exercises and rehearsals, where further assessment and refinement would yield greater efficiency and effectiveness. Successful implementation of the workflow at these events would assist in building helicopter aircrew confidence in the volunteer surveys. These HA/DR exercises would spur NGOs to develop procedures to implement and execute the Volunteer HLZ Survey Workflow.

5.2.1. Collaboration with OSM and Other NGOs on the Evolution of the Volunteer HLZ Survey Workflow

Initially, responsibility for the upload of HLZ data to OSM falls to the HOT editors, but improvements to the OSM application must be implemented to automate these processes. Automated processes shall help to reduce HOT editor workload and minimize potential human errors during HLZ data input and upload. The development of a Helicopter Landing Zone feature within OSM, with its fields tailored to the functional areas of the HLZ survey, would enable more efficient execution of the survey workflow. All of these functions must be executed by the HOT prior to and during actual HA/DR operations. Other NGOs will serve as the mechanism for refinement and execution of the training process for volunteers seeking to support HLZ surveys; these organizations would be able to tailor the training to the capabilities and technologies that particular entity makes available to its members and supporting volunteers.

5.2.2. Volunteer HLZ Survey Workflow Evaluation and Refinement via HA/DR Exercises

The developmental progression of the Volunteer HLZ Survey Workflow would benefit from its inclusion and further validation during a live HA/DR exercise. The optimal exercise for executing this evaluation and refinement would be the semi-annual Weapons and Tactics Instructor (WTI) Course conducted by Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) in Yuma, Arizona. MAWTS-1 is an advanced service-level aviation school, akin to the US Air Force Fighter Weapons School or the US Navy TOPGUN course. MAWTS-1 regularly conducts evaluations of cutting edge technologies, processes and tactics during the WTI courses, with its Advanced Developmental Tactics and Evaluation Department coordinating and facilitating these assessments. The WTI course includes at least one live HA/DR exercise, conducted in one of the urban areas of the American Southwest, and including significant involvement of helicopter and tiltrotor assets conducting logistical support. MAWTS-1, as the Marine Corps' service-level aviation school, would ensure that an evaluation of the Volunteer HLZ Survey Workflow would be properly planned and executed.

Integration of the workflow in the WTI course requires significant advanced planning and coordination. Courses occur every March/April and September/October; coordination begins with an initial planning conference six months prior to course execution. A summary of the workflow, and a concept of employment of its inclusion in the course, would need to be prepared for and presented at the initial planning conference. Requirements for role players and data systems infrastructure support would need to be presented at the next planning conference three months prior to execution. Final coordination would be execute at the final planning conference the week prior to the start of the course, with the MSEL and evaluation criteria reviewed and finalized. Execution of the HA/DR evolution normally occurs during the fifth week of the six=week course, with a full day of planning preceding the day of execution. The HLZs authorized for use during the evolution would need to be coordinated with civil authorities in the town chosen to host the HA/DR event well in advance, necessitating guiding the planners to use those sites vice ones they might select on their own. Marine helicopter aircrews would plan these HLZs with JMPS, and post the results to the HOT Web GIS. Concurrently to these actions, the volunteer surveyors would be trained on HLZ survey techniques. A role player serving as a representative from a NGO would download the HLZs for assignment to volunteers. These downloaded data would be used to task role players serving as volunteer surveyors. Survey results would be returned to the role player NGO representative for upload to the HOT Web GIS. Validation would occur when the aircrews actually fly the mission, and are able to provide ground-truth assessment on the credibility of the volunteer surveys.

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