User Hazard Guide: Latacunga, Ecuador

This is user hazard guide produced by a group of students from California University of Pennsylvania. The primary objective of this guide is to provide emergency management information pertaining to the city of Latacunga, Ecuador.

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Summary:

- An explanation of why the guide was created because of the recent volcanic activity of Mt. Cotopaxi back in August 2015 and other past eruptions and the damage they caused.

- The different volcano hazards of lava flow, pyroclastic flow, ash fall, mass wasting, earthquakes, and lahars were explained of Mt. Cotopaxi in relation to the city of Latacunga.

- General information was provided about mitigation was explained and how we can use GIS and humanitarian mapping in a data poor environment as Emergency managers to analyze, interpret effects, and create mitigation plans.

- If a volcanic eruption were to happen tomorrow InaSafe modeling results were provided about the number of buildings and roads they may become effected by the various hazards.

- General actions were provided to the people of Latacunga who lack public education tools in the event of an eruption.

- Actions were proposed as a contribution of California University of PA in the future like map-a-thons and an evacuation guide based on areas and people of risk from varying events. Along with more in depth mitigation techniques.

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Summary Briefing: *Latacunga, Ecuador*

Physical Description: The City of Latacunga, Ecuador is located on a large plateau. Standing at 9,055 feet above sea level, Latacunga is located only 20 miles away from the Cotopaxi Volcano, which is approximately 19,388 feet high ((Miller, D.C., D.R. Mullineaux, M.L. Hall).

Volcanic History: Cotopaxi is considered one of the worlds most dangerous volcanoes and continues to show activity to this day. In the past Cotopaxi had four destructive eruptions taking place in 1744, 1768, 1877, and 1904 that severely impacted Latacunga and several other surrounding areas (Miller, D.C., D.R. Mullineaux, M.L. Hall). These four eruptions were not the only few to occur, over 50 eruptions are on record but none as devastating as the four that took place in the years listed.

Economy: The Latacunga economy is dependent on agriculture and floriculture. It has one international airport, called Cotopaxi International Airport. Although it is not used for international passengers, it is used by the Ecuadorian Air Force base. It does have some special commercial flights that do take place. Though most of the economy is driven from the agricultural business, other means of income are due to tourists. The Cotopaxi Volcano is the main driving force for tourism, however, other environmental attractions include the two rivers located near Latacunga, known as Alaques and Cutuchi. For an agricultural driven economy, any type of volcanic eruption will severely impact Latacunga by damaging the crops, ruining the water systems, and from preventing proper sunlight from ash plumes .

Climate: Latacunga is classified as a warm temperate climate. But, as Latacunga is on a high plateau, the climate is generally cooler, with windbreakers or barriers leaving the area quite breezy throughout the year. Latacunga receives a very high amount of rainfall throughout the year even during the driest months. Approximately 515 millimeters of precipitation happens annually (Miller, D.C., D.R. Mullineaux, M.L. Hall, 1978). The temperature usually averages around 13.4 Celsius.

Reason for Concern:

In August 2015, Cotopaxi has made noise for the first time in 70 years. Since then, it has shown an almost constant release of steam as well as small ash plumes originating from small explosions (Leonard, G.S., Johnston, D.M., Williams, S., Cole, J.W., Finnis, K. & Barnard, S., 2005). This shows that magma is slowly rising into the volcano. There is no significant way to tell when a volcano will erupt, but precursors like changes in gas, tilt, and seismic activity can give scientists a general idea when there might be a possible eruption. The volcano is already causing problems for the nearby National Park, where there have been reports of a few millimeters of fine ash falling throughout the park (Leonard, G.S., Johnston, D.M., Williams, S., Cole, J.W., Finnis, K. & Barnard, S., 2005). The ash is already impacting local communities. Due to the farmers the Ecuadoran government has began preparing for evacuations.

The potential estimated damage could affect up to 500 million people in the next major eruption (Leonard, G.S., Johnston, D.M., Williams, S., Cole, J.W., Finnis, K. & Barnard, S., 2005). As of 2010, 98,355 people are located in Latacunga with no where to hide from such a explosive. An evacuation plan will be implemented to the Latacunga people to help reduce severe injuries or even death. The President of Ecuador Rafael Correa has declared a state of emergency for the increasing activity of the Cotopaxi volcano. The Cotopaxi volcano is very close to the capital of Quito, officials have been taking the active volcano seriously and already evacuated a few hundred people. The follow guide that we created will assist as a public education tool in information and mitigation.

Mitigation

Mitigation is the effort to reduce loss of life and property by lessening the impact of disasters. In order for mitigation to be effective, action must be taken before the next disaster. Preparing beforehand will reduce human and financial consequences later. Disasters can happen anywhere and unexpectedly and if not properly prepared, consequences can be fatal and financially devastating.

Hazards Mitigation

Volcanoes are natural processes that cannot be prevented or stopped. However, reduction of risk and the consequence of such volcanic eruptions can be used. Diversion and other control of mudflows, lava flows, and other results of eruptions are expensive, and limited in terms of its effectiveness. In general, proper mitigation means making plans to lessen consequences well before an eruption event occurs. Areas of potentiality high risk, moderate risk, and low risk during an eruption should be identified clearly on a map and communicated. In order to ensure the safety of life and property, anyone within the high-risk zone should be evacuated during an eruption event. Knowing when an eruption is going to occur is very difficult to predict, and often once a volcano has erupted, it is too late for proper mitigation actions to be effective. Therefore, monitoring volcanic activity with instruments before an eruption provides the best evidence as to whether or not a volcano is nearing an eruption. Smaller eruptions and "side-effects" such as rock falls, minor mudflows, flooding, and ash-fall are all viable signs that a volcano is active and could be potentially nearing a larger scale eruption. Studying such events and other data provides awareness to a potentially dangerous scenario. Once an eruption seems imminent, planning and communication are critical. This is done through local and federal agencies such as the Ecuadorian Civil Defense. Local government officials, business groups, citizens, and tourists need to be notified of the current situation in a clear and concise manner. Instructions should include information relative to the effects of the current hazard(s), type of secondary hazard(s) that could arise, probable severity, expected effects from the hazard(s), and what people should do if an eruption does occur. Citizens should also be informed about taking their own initiative and have a plan developed for how they will respond to such a hazard(s). This can include possible evacuation.

Humanitarian Mapping

Mapping in remote areas requires knowing the locations that need the most assistance. Not only knowing which areas are in the most need, but also the safest and quickest route to get to these areas. Many remote areas do not have an up-to-date map to use for planning purposes or disaster events. This is where Humanitarian OpenStreetMap can be helpful. It uses crowdsourcing to create digital maps. Crowdsourcing is the process of outsourcing work to a larger population. In OpenStreetMap, anyone can create a user account, log on, and begin mapping important features. Programs such as OpenStreetMap have tools to trace roads, buildings, and other polygons, which can be labeled as a variety of things. Parking lots, boat docks, and open fields are just some examples of such labels ("Mapping Humanitarian Action – a Fast-developing Sector.").

OpenStreetMap allows every person around the world to collect data to assist in a disaster. If more people map before a disaster occurs, then planning and rescue could be accomplished faster because the data would provide helicopters knowledge on where it is safe to land as an example. The International Committee of the Red Cross is an example of an organization that depends on crowdsourced data to assist regions that need their help. For example, the organization uses OpenStreetMap to determine where clean water is in the highest demand, as well as the best locations to lay pipes for water to reach beneficiaries.

Having data from OpenStreetMap helps because it offers visual aid for responders. Without knowing where buildings and streets are located, if streets connect, or where possible safe locations may be located it is challenging to plan routes for rescue. When a disaster occurs time is crucial. Planning the most efficient rescue can be done with the right data and many lives can be saved.

Image from:
Mitchell, Greita. "OSM – OpenStreetMap." *Esri South Africa Blog*. N.p., 16 Sept. 2015. Web. 04 June 2016.

Using GIS Software for Emergency Management

When a disaster occurs, knowing where the hazards are and where people live and work relative to the risks is essential to understand how to provide relief to the affected people. GIS can be used across all sectors of Emergency Management: for situational awareness, identifying ideal locations for prepositioning assets ahead of an impact, understanding the relationship between hazard exposure and social vulnerability as part of the hazard mitigation planning process, and more. Essentially if you have data, it can be mapped, analyzed and utilized to make better decisions in a responsible amount of time. GIS models and simulations enable decision makers to exercise both response and recovery plans pre and post disasters and also understand possible events. During a disaster two common models ran for Volcanic Hazards are ESRIS' HAZUS and QGIS' InaSAFE. Data can be pulled as shapefiles from OpenStreetMap and used by response organizations like FEMA and USAID.

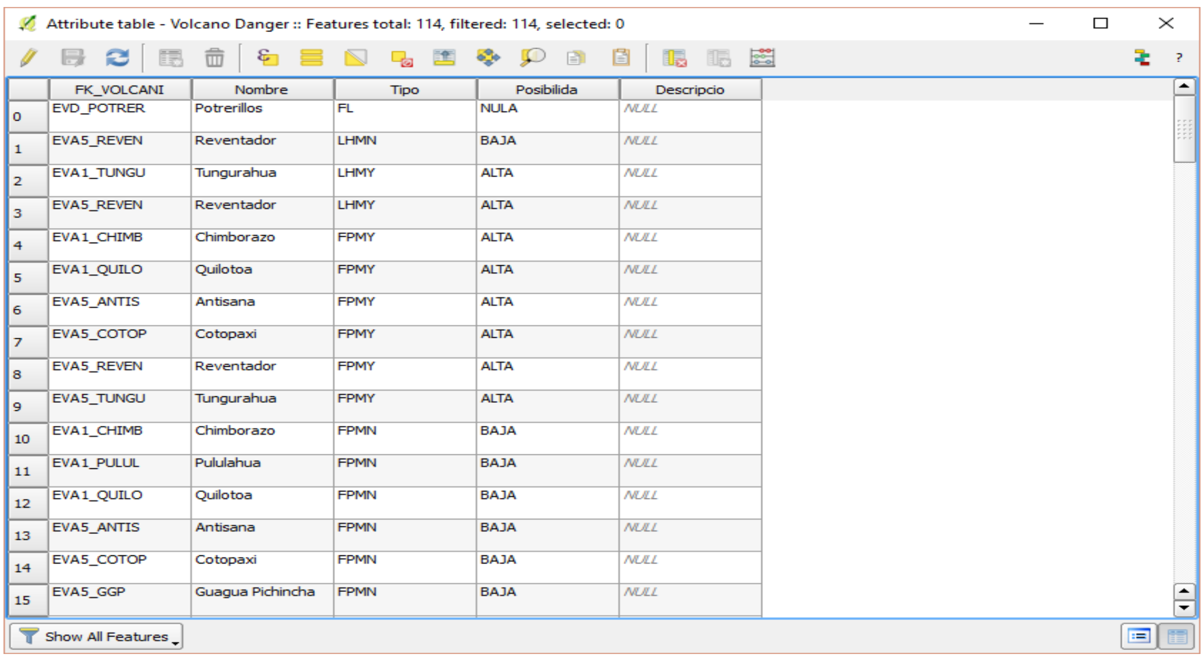
QGIS InaSafe: InaSAFE is free software that produces natural hazard impact scenarios to aid in planning, preparedness, and response activities. It provides a simple but rigorous way to combine data from scientists, local governments, and communities to provide insights into the likely impacts of future disaster events (InaSafe). InaSafe is what was used to run reports for the City of Latacunga's infrastructure.

HAZUS: Is a product plugin from FEMA in ArcMap that helps users make informed decisions. Estimates potential losses from earthquakes, floods, and hurricanes and visualizing the effects of such hazards. However, HAZUS reports were not used in our analysis of Latacunga because we did not have access to the specific parameter layers the software needs for a successful output.

QGIS & ESRI ArcMap:

QGIS and ArcMap are both commonly used GIS mapping software. It is a way to take spatial data and represent it as a map, represented in either raster or vector format. A raster is a uniform grid collection of pixels with assigned values. Raster models are useful for storing data that varies continuously, such as aerial photography or satellite imagery. A vector is made of paths, and creates points , lines, and polygons. Vectors are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets.

To use data in this software, its good to have it stored in attribute tables. Attribute tables are arranged by rows and columns. Rows are known as records and columns are fields. Each field can store a specific type of data such as a number, date, or text. Here is an example of an attribute table from the Mt. Cotopaxi data set Volcanic Danger layer:



	FK_VOLCANI	Nombre	Tipo	Posibilida	Descripcio
0	EVD_POTRER	Potrerillos	FL	NULA	NULL
1	EVA5_REVEN	Reventador	LHMN	BAJA	NULL
2	EVA1_TUNGU	Tungurahua	LHMY	ALTA	NULL
3	EVA5_REVEN	Reventador	LHMY	ALTA	NULL
4	EVA1_CHIMB	Chimborazo	FPMY	ALTA	NULL
5	EVA1_QUILO	Quilotoa	FPMY	ALTA	NULL
6	EVA5_ANTIS	Antisana	FPMY	ALTA	NULL
7	EVA5_COTOP	Cotopaxi	FPMY	ALTA	NULL
8	EVA5_REVEN	Reventador	FPMY	ALTA	NULL
9	EVA5_TUNGU	Tungurahua	FPMY	ALTA	NULL
10	EVA1_CHIMB	Chimborazo	FPMN	BAJA	NULL
11	EVA1_PULUL	Pululahua	FPMN	BAJA	NULL
12	EVA1_QUILO	Quilotoa	FPMN	BAJA	NULL
13	EVA5_ANTIS	Antisana	FPMN	BAJA	NULL
14	EVA5_COTOP	Cotopaxi	FPMN	BAJA	NULL
15	EVA5_GGP	Guagua Pichincha	FPMN	BAJA	NULL

On the above table, the rows are the records of different volcanic dangers across the region. The columns are different fields: the volcano name, the type of danger, and the possibility of it occurring. From the dataset you can see the information was published in Spanish, which can cause difficulties, as sometimes it may take longer to translate data.

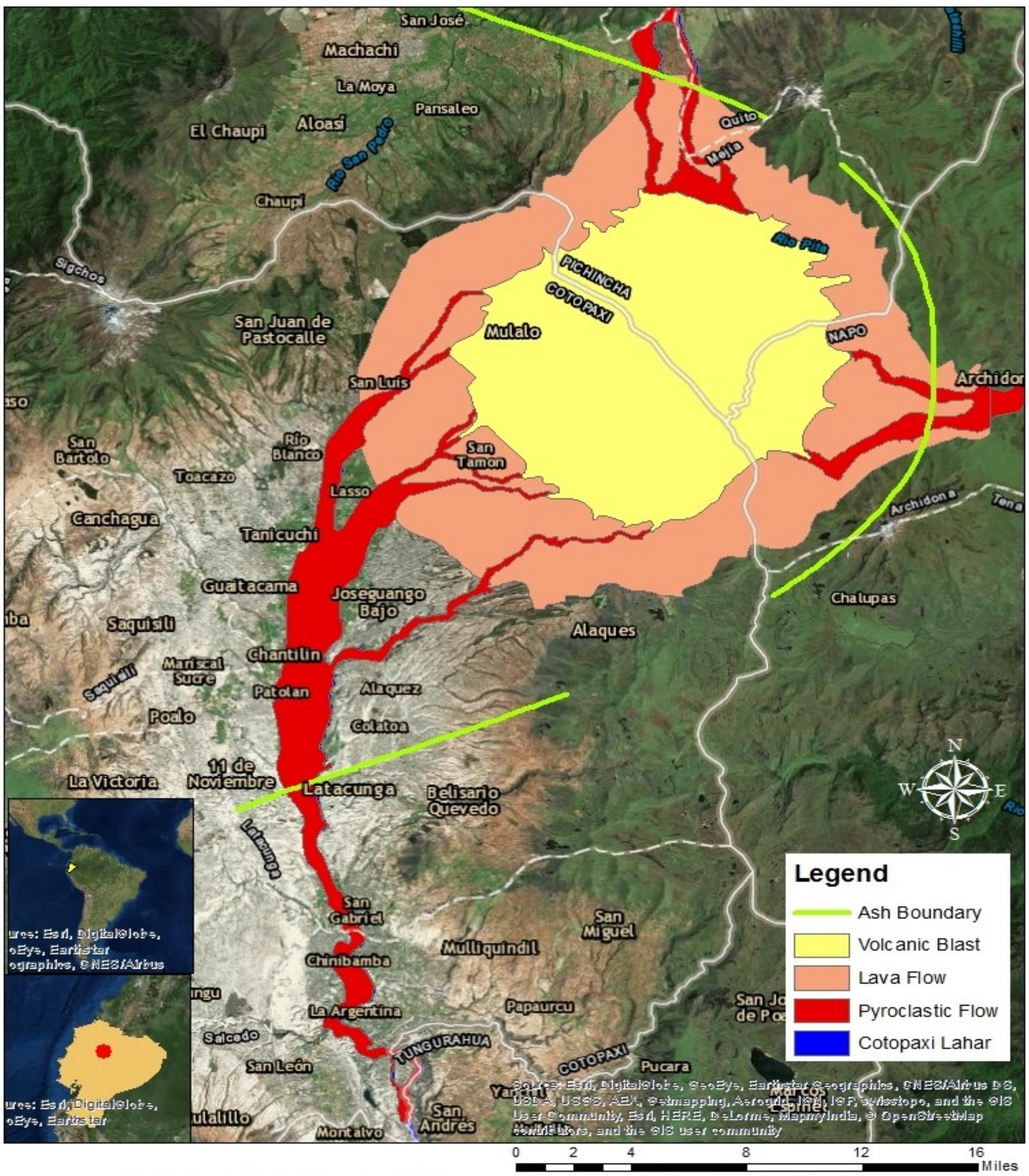
A common analysis method is known as a query where attributes are selected by particular records or fields. Queries can be ran to define one or more criteria . For example, running "Select by Attributes" query on the table above could select and highlight data lahar flows specific to Mt. Cotopaxi that show a high possibility of occurring. The Select By Location dialog box allows feature selection based on their location relative to other features: such as querying for how many educational buildings are within 200 feet of a lava flow path.

Section 1: General Information

Volcanic Hazards

Volcanic eruptions produce either molten and/or solid rock debris that are blown high into the atmosphere. The debris falls back to earth's surface (ash deposits) or flow directly from the volcano onto the ground's surface (lahars, lava, and pyroclastic flows). The severity of such hazards depend solely on the destructiveness of the eruption, types of materials disposed by eruption, and the volume of the disposed materials. An eruption of Mt. Cotopaxi could result in ash fall deposits, and one or more kinds of flow deposits. These are discussed in the following sections.

General Volcanic Hazards of Mt. Cotopaxi

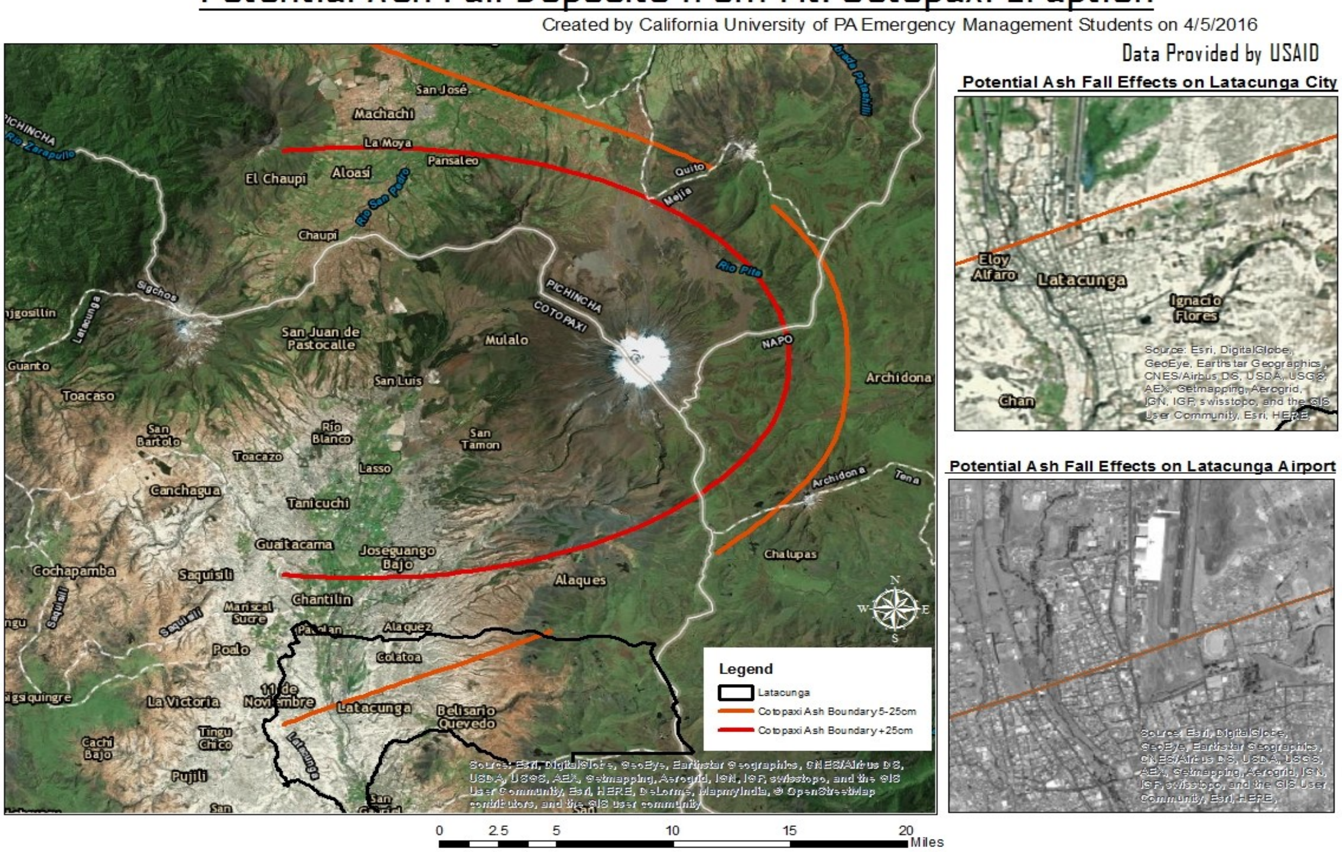


Created by California University of PA Emergency Management Students on April 1st, 2016
Data Provided by USAID

Ash Fall Deposits

Volcanic ash is typically carried by wind in any direction, but it is most likely to be carried by the dominant winds in a westerly or northwesterly direction. It is less likely (but still possible) to be carried in a southwest or north direction (.Miller, D.C., D.R. Mullineaux, M.L. Hall). Additionally, it is highly unlikely for ash deposits to move in the easterly direction as this is opposite to the dominant wind direction which flows east to west. Thus most damage from future ash deposits are expected to be to the west of Mt. Cotopaxi. Cities such as Mulalo and Lasso are the most at risk for ash fall deposits. Latacunga is southwest of Cotopaxi and as a result is less likely to see damage. The likelihood of abundant ash moving to the south and south-west is low. However, ash fall is still possible and has affected Latacunga in the past. According to past ash fall deposits, cities located within 15 - 20 km to the west can see no more than a couple of centimeters of ash fall (Miller, D.C., D.R. Mullineaux, M.L. Hall). However this is reduced to less than a centimeter with a distance greater than 50 km. A major eruption can produce as much as a meter of ash at a distance of 15 - 20 km and several centimeters up to a distance of 50km. Latacunga has historically seen minor ash deposits of less than a centimeter, with maximum deposits of 4 - 7cm during the historic eruption of 1877 (Miller, D.C., D.R. Mullineaux, M.L. Hall). Receiving ash deposits greater than a 1 cm is unlikely. Damages due to ash fall are minor to moderate in its effects. Ash fall can produce darkness, confusion, and panic in downwind cities such as Latacunga. Agriculture and livestock can be damaged. People vulnerable to respiratory issues such as the young, elderly, and those with respiratory problems may be affected if not using protection (such as a mask). Water supply for both drinking and irrigation can be affected if proper mitigation tech-niques are not used. Latacunga's local airport and air force base may experience problems due to lack of visibility. Additionally ash is extremely dangerous to an airplane's engines and therefore all flights are grounded during ash fall events. Loss of life due to ash fall events is also extremely unlikely.

Potential Ash Fall Deposits from Mt. Cotopaxi Eruption



Lahars & Mudflows Flooding

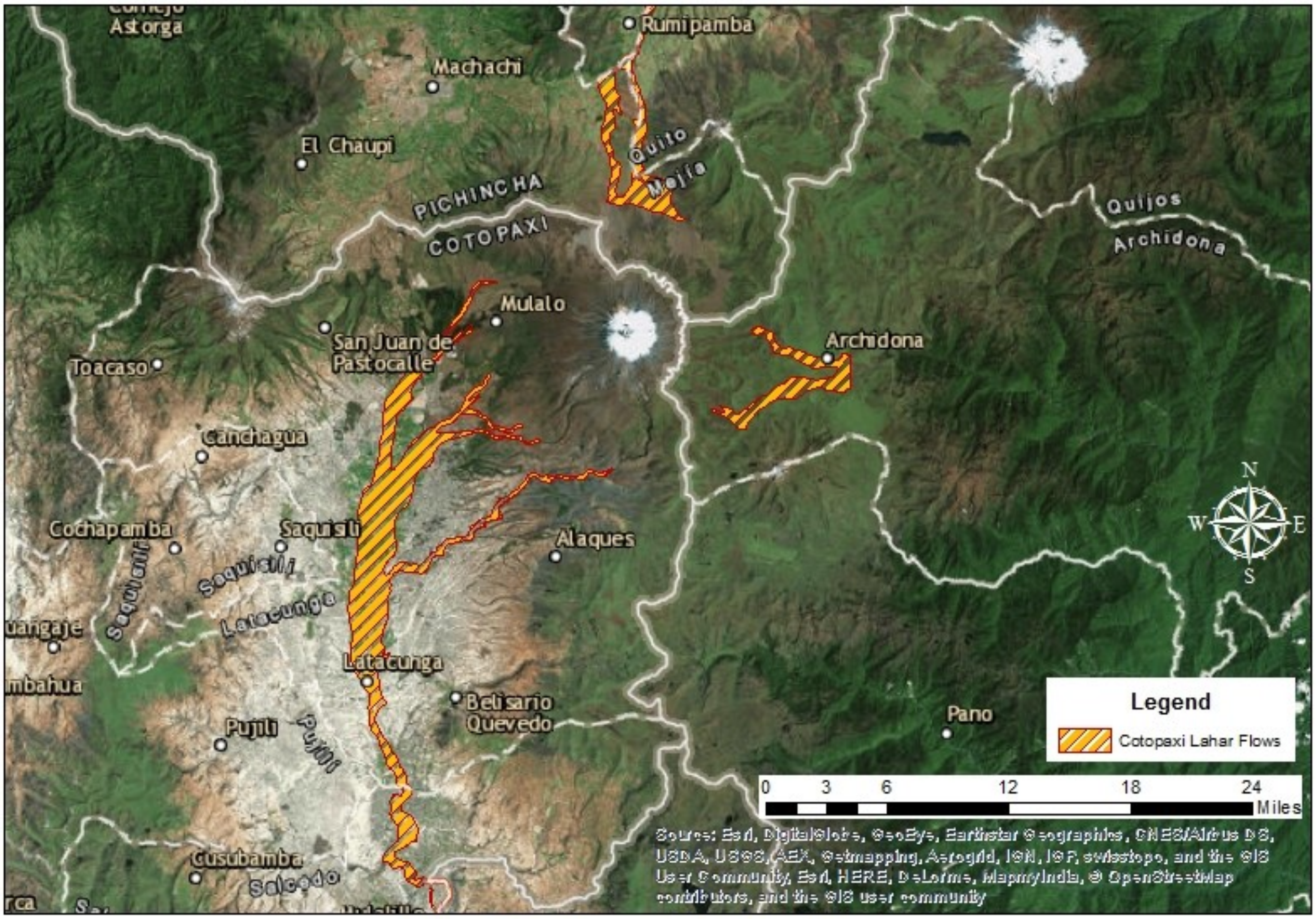
A lahar is a type of mudflow or debris flow that occurs during an eruption of a volcano. It is composed of slurry of pyroclastic material, rocks, and water. The material flows down from a volcano, typically along drainage streams and larger river valleys. Eruptions may trigger one or more lahars directly by quickly melting snow and ice on a volcano. This additional dangerous amount of water can easily erode loose volcanic rock and soil on hillsides and in river valleys. Mudflows and floods can be expected to be major hazards from future eruptions of Mt. Cotopaxi from lahars. These events are generally restricted to three large drainage basins. The River Patate flows southwest into the Latacunga Valley. The Rio Tambo and Rio Tamboyacu flow eastward to form the Rio Napo. The Rio Pita flows northward into the valley of the Rio Pita (Susanne Ettinger (1), Patricia Mothes (2), ft Raphaël Paris (3)) .

Latacunga has frequently been affected by small and large mudflows and floods in its historic and geologic past. The city can be divided into two zones: a severe hazard zone, and a moderate hazard zone (.Susanne Ettinger (1), Patricia Mothes (2), ft Raphaël Paris (3)). Parts of Latacunga that lie within the River Patate Valley are projected to be in the severe hazard zone during future eruptions of Cotopaxi.

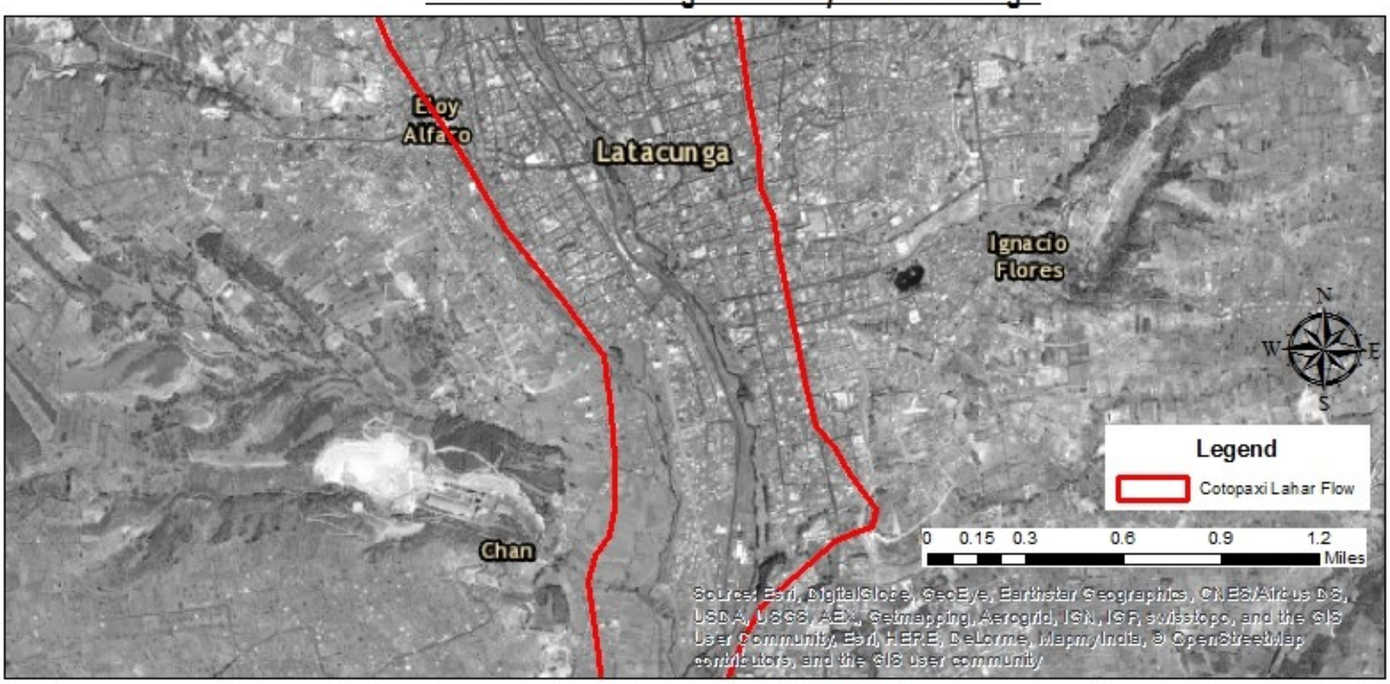
The River Patete Drainage Basin into Latacunga from Mt. Cotopaxi

Lahar Flow from Mt. Cotopaxi

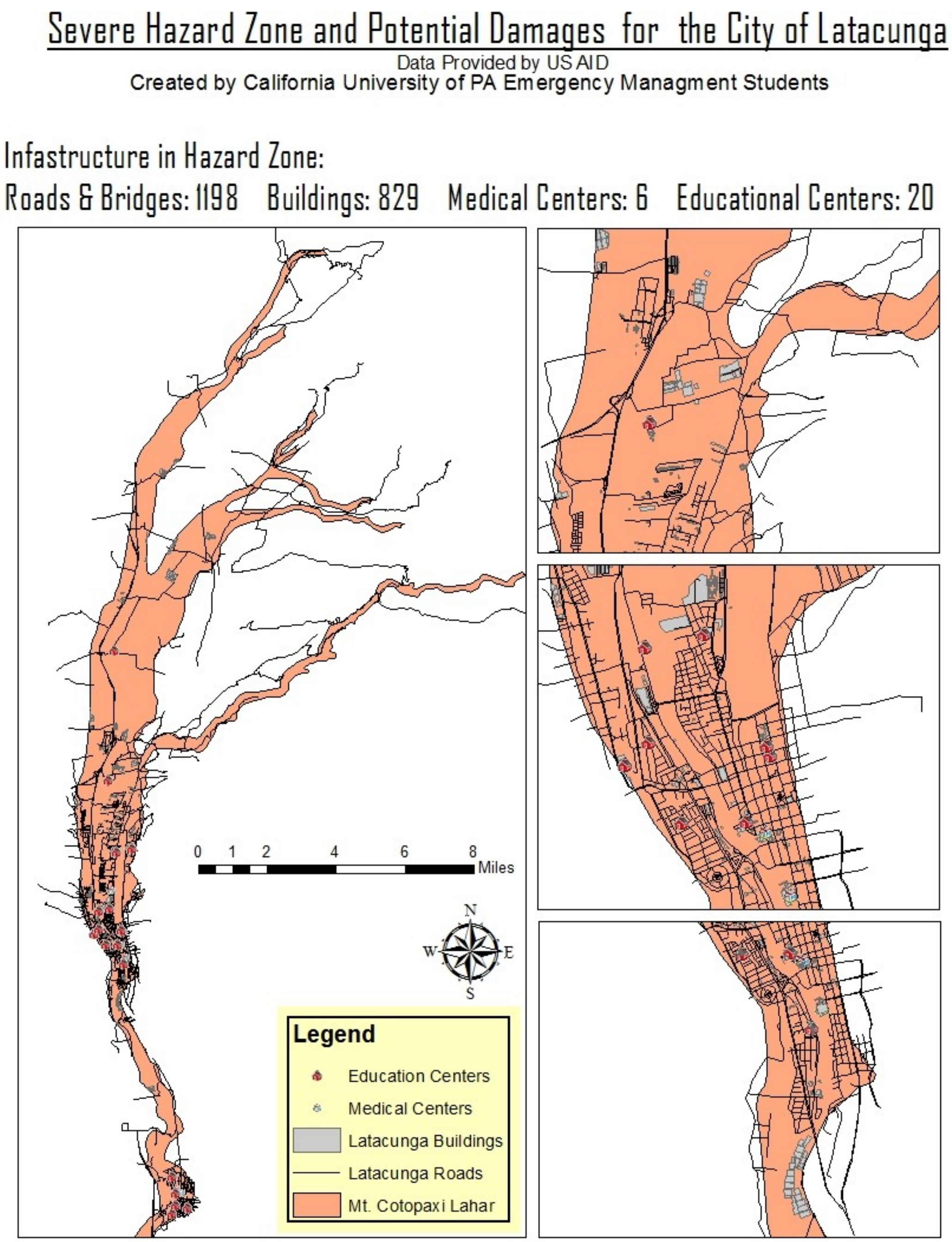
Data Provided by USAID
Created by California University of PA Emergency Management Students on 4/4/2016



Lahar Flow Through the City of Latacunga



The severe hazard zone mentioned earlier from Mt. Cotopaxi lahars includes stream channels in the River Patate, adjacent stream channels, and areas that are several meters above the River Patate's channel floor. Within the severe hazard zone, the stream and River Patate's channel floors are the most hazardous places. Safety increases as height increases above the channel floor. The severe hazard zone is affected by frequent hazards. Several river valleys lead westward from Mt. Cotopaxi that are subject to mudflows from future eruptions of Mt. Cotopaxi. These rivers include the Rio Cutuchi west of Cotopaxi and all of the valleys that lie south of the Cutuchi to and including the Rio Alaquez (Susanne Ettinger (1), Patricia Mothes (2), ft Raphaël Paris (3)). A zone of severe hazard extends across much of the valley floor between the Rio Cutuchi and Rio Saquimala, and includes the broad area west of Mulalo, the town of San Felipe, and the westernmost region of Latacunga (.Susanne Ettinger (1), Patricia Mothes (2), ft Raphaël Paris (3)). All the valley floors and low terraces of major rivers flowing from the west side of Mt Cotopaxi are also included in this area of relatively frequent mudflow and flood hazards. Very large mudflows and floods could also be expected to spread across the moderate hazard zone. This zone includes most of all the valley floors of the Rio Cutuchi and Rio Saquimala, the town of Lasso, and much of Latacunga. In the valley of the Rio Cutuchi, from the Cerrito del Callo south to Latacunga, mudflows and floods would endanger the Pan American Highway, railroads, many bridges across the Rio Cutuchi, Saquimala, Alaquez and Patate, and the Latacunga Airport.



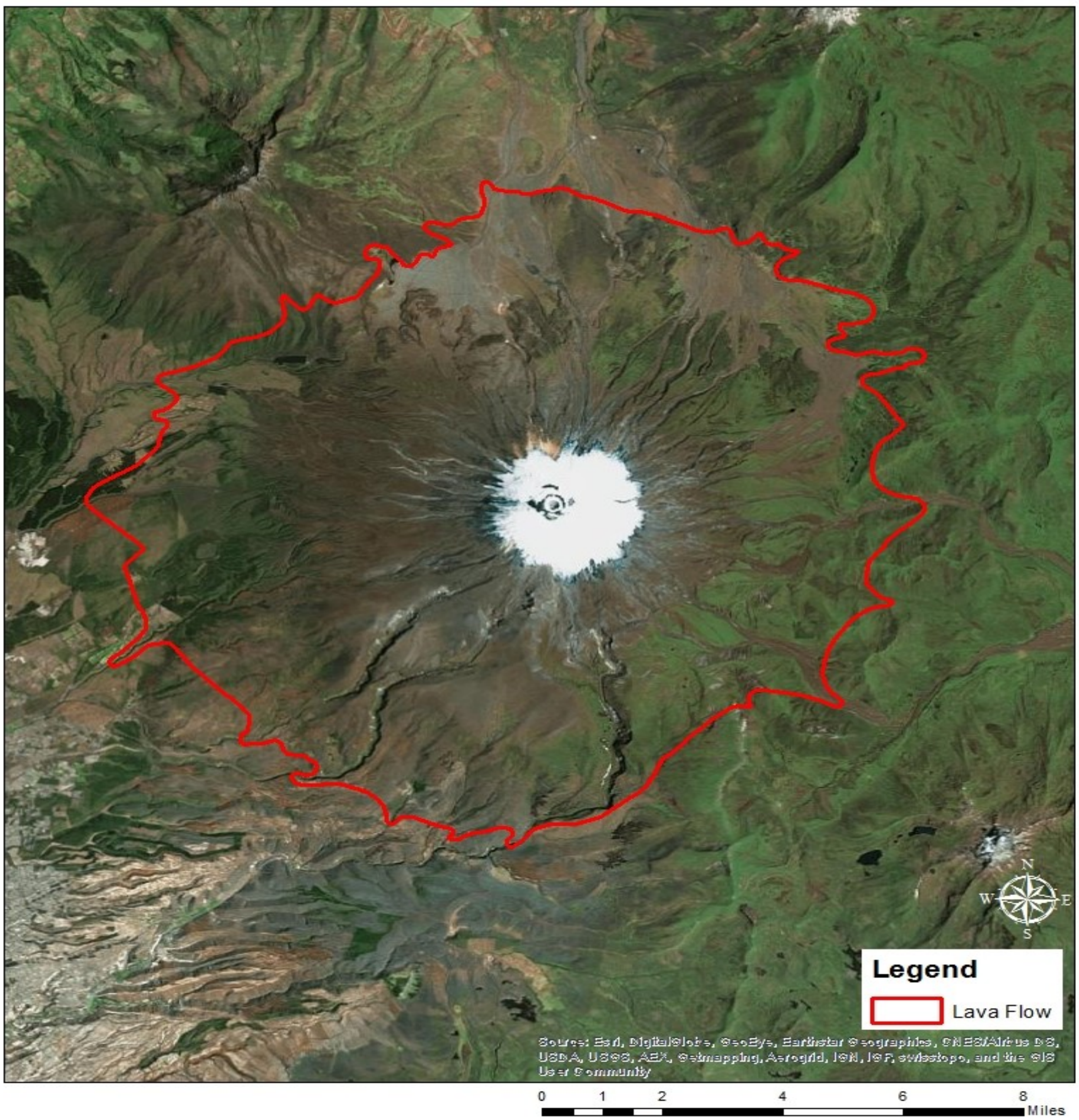
Within the severe hazard zone lies 1198 roads, 829 buildings, 6 medical centers, and 20 educational centers.

Lava Flows

Lava flows are slow moving coherent streams of hot, viscous, molten rock. The average speed for lava flows is generally slower than a few meters per hour which is slower than a person can walk. Lava flows can set anything they touch ablaze and can alter the landscape. Lava flows generally do not flow much farther than the flanks of the volcano itself. They are extremely local hazards and therefore do not affect Latacunga, which lies 25 km to the southwest Mt. Cotopaxi. However lava flows can melt much ice and snow on Mt. Cotopaxi, which in return can cause flooding and mudflows downstream. Therefore, lava flows indirectly affect Latacunga due to flooding and mudflows that can cause large amounts of snow and ice melt.

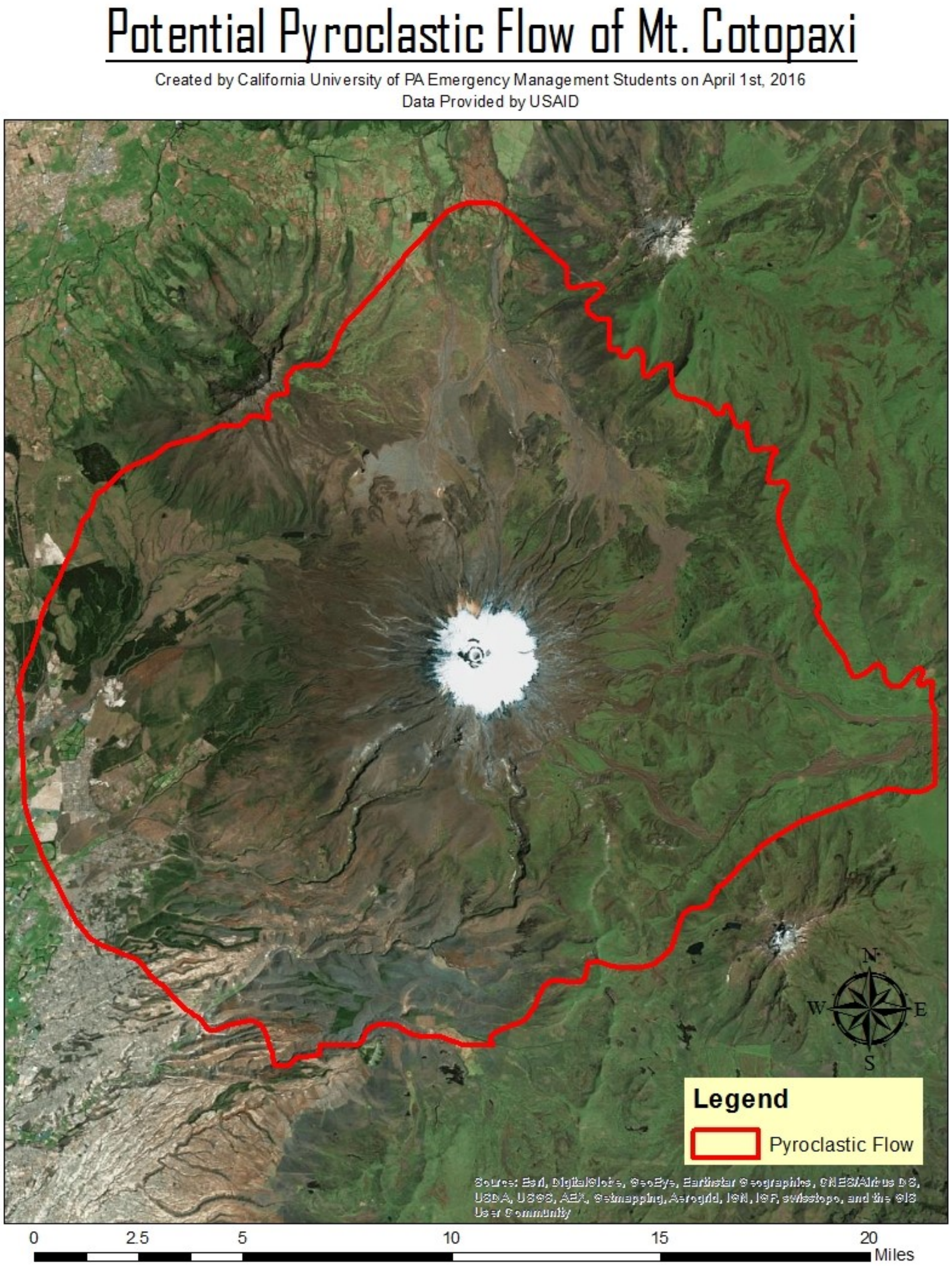
Potential Lava Flow of Mt. Cotopaxi

Created by California University of PA Emergency Management Students on April 1st, 2016
Data Provided by USAID



Pyroclastic Flows

Pyroclastic flows contain a high-density mix of hot lava blocks, pumice, ash, and volcanic gas. Pyroclastic flows move at very high speed down volcanic slopes, typically following valleys. Most pyroclastic flows consist of two parts: a lower (basal) flow of coarse fragments that moves along the ground, and a turbulent cloud of ash that rises above the basal flow. Ash may fall from this cloud over a wide area downwind from the pyroclastic flow. With rock fragments ranging in size from ash to boulders that travel across the ground at speeds typically greater than 80 km per hour (50 mph), pyroclastic flows knock down, shatter, bury or carry away nearly all objects and structures in their path. The extreme temperatures of rocks and gas inside pyroclastic flows, generally between 200°C and 700°C (390-1300°F), can ignite fires and melt snow and ice. Pyroclastic flows vary considerably in size and speed, and can destroy buildings, forests, and farmland. People and animals may result in death and serious injury from burns and inhalation of hot ash and gases. Pyroclastic flows generally travel no more than 10-15 km. However the ash from such pyroclastic flows can travel upwards of 200 km from its source. They can also cause secondary hazards including flooding and mudflows by eroding, rapid melting, and mixing with snow and ice: creating a sudden torrent downstream. Longer lasting hazards include increasing the rate of stream runoff and erosion during rainstorms due to the creation of easily eroded landscape with sparse vegetation. Damming or blocking streams in volcanic valleys can create lakes behind the blockage, which may eventually overtop and collapse producing a rush of water and volcanic material causing flooding and mudflows downstream.



Seismic & Other Geologic Hazards

A geologic hazard is an extreme natural event in the crust of the earth that poses a threat to life and property. Examples include earthquakes, volcanic eruptions, tsunamis, mass wasting, and faulting. Tsunamis are not a threat for Latacunga and therefore, this section will focus solely on earthquakes, faulting, and mass wasting.

Earthquakes & Faulting

Latacunga is located in the Inter-Andean Depression along the Pisayambo Fault. This region is tectonically active due to the oceanic Nazca Plate subducting the continental South American Plate (Ert, J.weW.; Murray, T.L.; Lockhart, A.B.; and Miller, C.D., 1993). The Nazca Plate is responsible for the uplifting of the Andes Mountains and its volcanic activity.

Latacunga is subject to great risk for faulting hazards and earthquakes. There are many faults surrounding Latacunga. The Pisayambo Fault is a reverse strike slip fault, which runs through Latacunga (Ert, J.weW.; Murray, T.L.; Lockhart, A.B.; and Miller, C.D., 1993). Reverse strike slip faults are less frequent and result in larger sudden movements compared to other types of faults. Earthquakes usually follow faults, as they are naturally weak boundaries in the earth's crust. Faulting results in movement along the fault line and can drastically alter the landscape along the fault area.

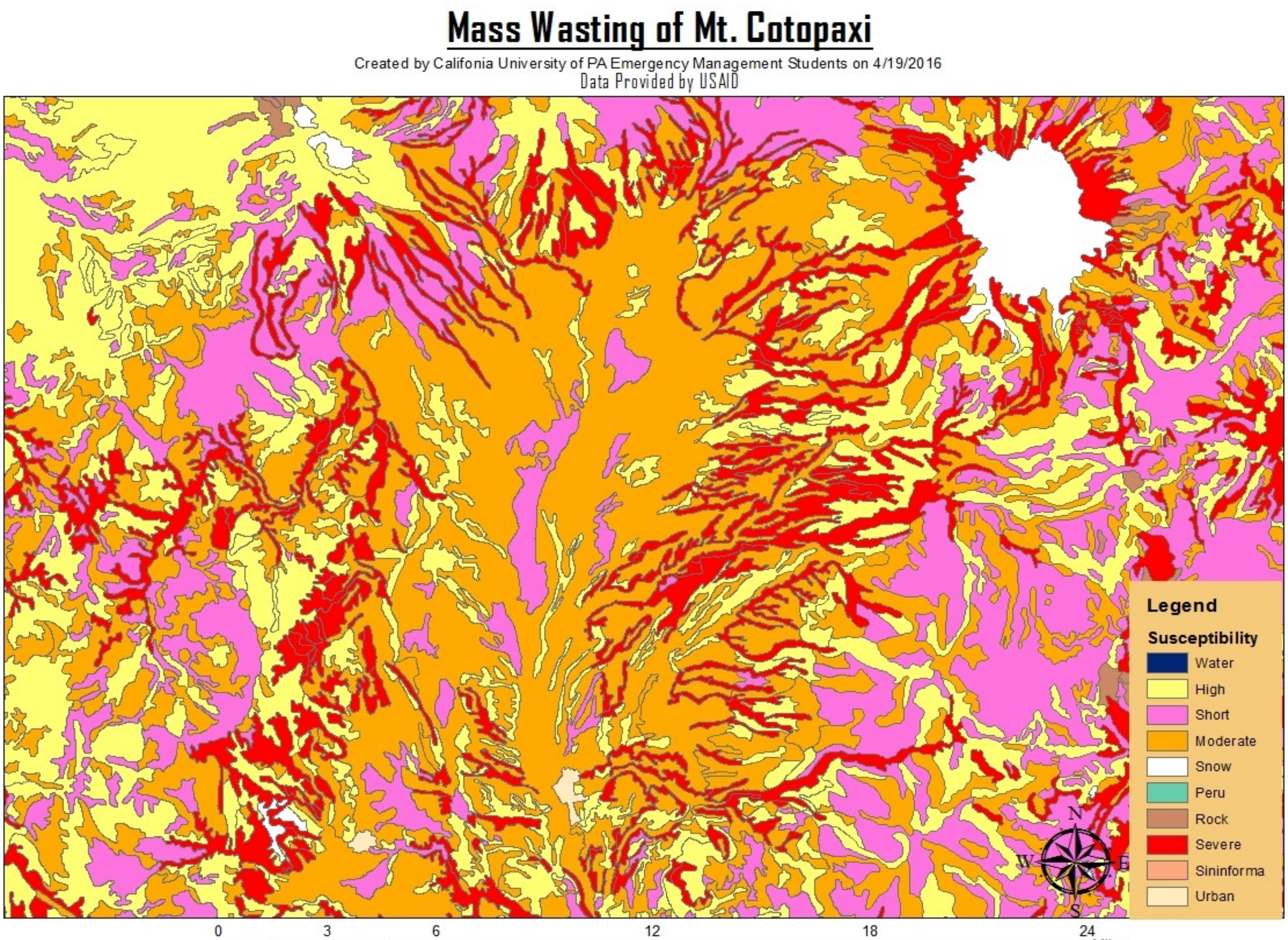
Faulting causes the shaking of the ground, which may last from seconds to minutes. Faulting can level any standing structures, tear up roadways and railroads, and cause minor uplift and subsidence. The affects of faulting depend solely on movement severity along the fault.

Earthquakes are a common hazard for Latacunga, and can range from unnoticeable tremors to severe and devastating events. Latacunga's strongest recorded earthquake was a 8.0 magnitude on the Richter scale and resulted in an estimated 100 - 1000 deaths (Ert, J.weW.; Murray, T.L.; Lockhart, A.B.; and Miller, C.D., 1993). Earthquakes cause the ground to violently shake for seconds to even hours. Earthquakes can cause major destruction to infrastructure both above and below the ground. The severity of the destruction depends on the magnitude of the earthquake. Latacunga sees frequent minor and unnoticeable earthquakes, however there is an enhanced risk for the occurrence of major earthquakes (>5.0 magnitude)(Alvarado, A., L. Audin, J. M. Nocquet, S. Lagreulet, M. Segovia, Y. Font, G. Lamarque, H. Yepes, P. Mothes, F. Rolandone, P. Jarrin, and X. Quidelleur 2014). Latacunga has the chance for one 6.0 magnitude or greater once every 50 years. Earthquakes can cause many secondary hazards such as mass wasting, flooding, and faulting.

Image from : Alvarado, A., L. Audin, J. M. Nocquet, S. Lagreulet, M. Segovia, Y. Font, G. Lamarque, H. Yepes, P. Mothes, F. Rolandone, P. Jarrin, and X. Quidelleur (2014), Active tectonics in Quito, Ecuador, assessed by geomorphological studies, GPS data, and crustal seismicity, Tectonics, 33, 67–83,

Mass Wasting

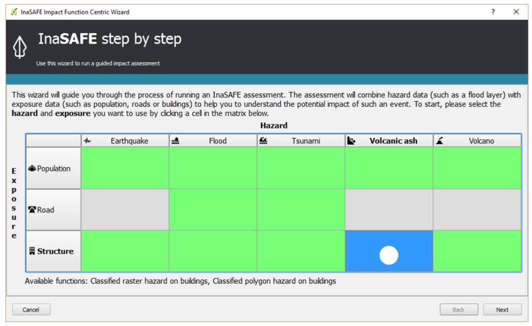
Mass wasting (also called mass movement or slope movement), is defined as the large downward movement of rock, soil and debris due to the force of gravity. Mass wasting is a type of erosion capable of making drastic changes to the landscape of a mountain. These changes can happen suddenly or happen slowly over time. This process is sometimes used interchangeably with landslide. However, the term landslide is limiting and does not allow for a description of the many different triggers and types of erosion that can happen on a large scale. Mass wasting can be caused by other hazards including flooding, earthquakes, and even volcanic eruptions. Mass wasting occurs when erosion reduces the shear strength, so that the force of gravity is now stronger than the shear force (force maintaining the slope's shape and position). The soil material is no longer able to resist gravity and 'wastes away" downslope. The steepness of the slope, type of materials, and amount of water all affect the possibility of mass wasting occurring. Increased steepness, increased amount of water or saturation, and weaker (more easily eroded) materials can increase the likelihood of a mass wasting event. Mass wasting affects any persons, living things, and infrastructure that is situated near the top of a slope, along a slope, or at the bottom of the slope. These areas are subject to both minor erosion events, but also major mass wasting events. Therefore these areas are areas of high risk and building infrastructure and residence in these areas are strongly discouraged. Notice in the map below the hillsides of Mt. Cotopaxi are susceptible to erosion below the snow covered mountain and Latacunga lies at the bottom of the slope receiving all the damage that may occur from these high susceptible slopes.



Section 2: Results from InaSafe Reporting

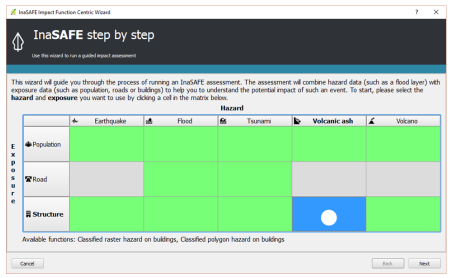
Summary Steps for Ash Fall Deposits on Effected Roads, Buildings, Educations Buildings , and Medical Centers

Step 1: Defined ash fall deposits as the hazard layer, and indicated an analysis on structures and roads (Figure 1).



(Figure 1)

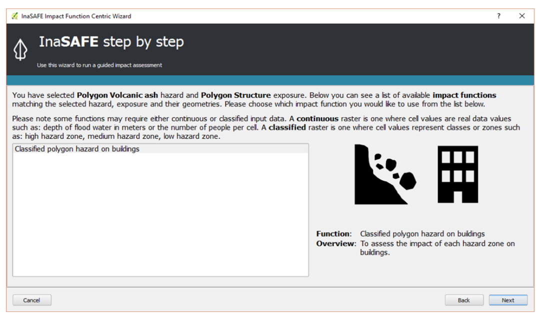
Step 2: Defined outcome of the result on the affected layers. The hazard layer of ash falls was a polygon, which was created using the line of impact to calculate damages within the expected ash fall path (Figure 2). Roads and buildings were also defined as polygons, and education buildings and medical centers were points (Figure 3).



(Figure 2)

(Figure 3)

Step 3: The specific hazard layer was defined for the analysis as an ash fall polygon which was already loaded into QGIS (Figure 4).



(Figure 4)

(Results)

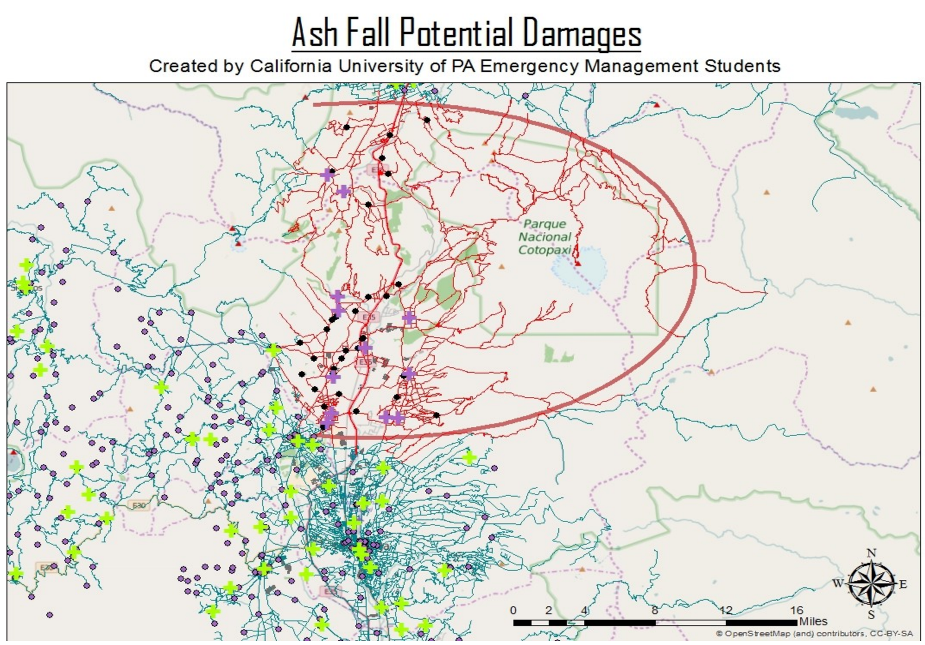
Results of the ash fall InaSafe report for roads, buildings, education buildings, and medical centers within danger are the following:

Education Buildings: 42

Roads: 755

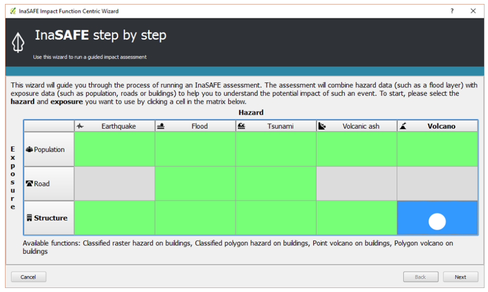
Buildings: 409

Medical Centers: 12



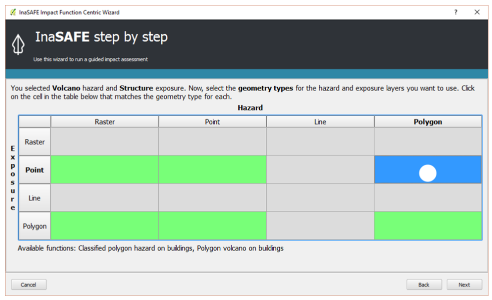
Summary Steps for Lava Flow on Effected Roads, Buildings, Educations Buildings , and Medical Centers

Step 1: Defined lava flow as the hazard layer, and indicated an analysis on structures and roads (Figure 1).

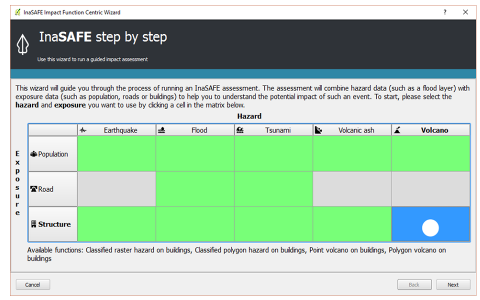


(Figure 1)

Step 2: Defined outcome of the result on the affected layers. The hazard layer of lava flow was a polygon. Roads and buildings were also defined as polygons (Figure 2). Education buildings and medical centers were points (Figure 3).

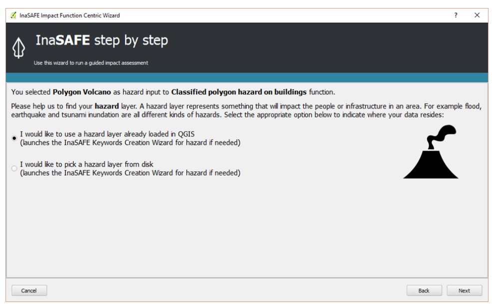


(Figure 2)



(Figure 3)

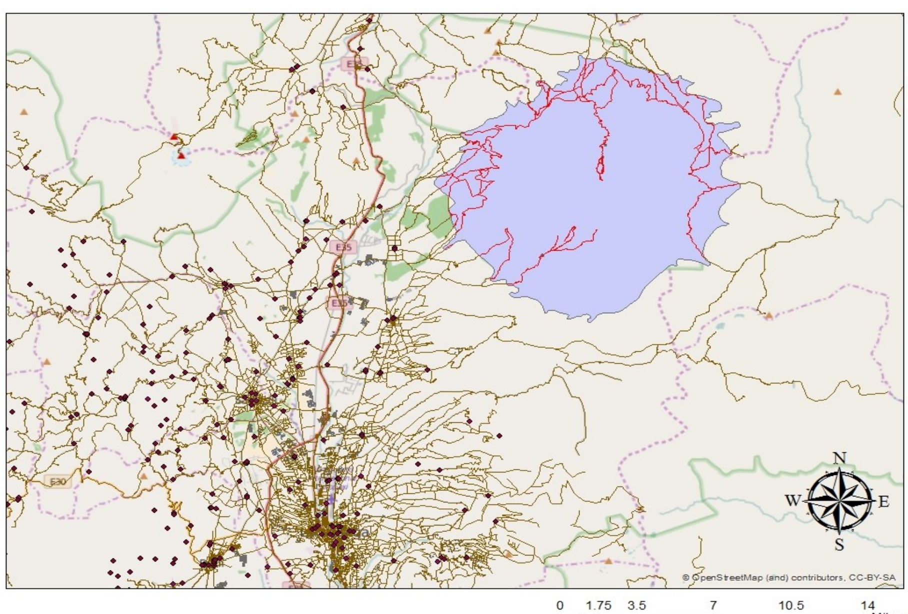
Step 3: The specific hazard layer was defined for the analysis as a lava flow polygon which was already loaded into QGIS (Figure 4).



(Figure 4)

Damages of Lava Flow

Created by California University of PA Emergency Management Students



(Results)

Results of the lava flow InaSafe report for roads, buildings, education buildings, and medical centers within danger are the following:

Education Buildings: 0

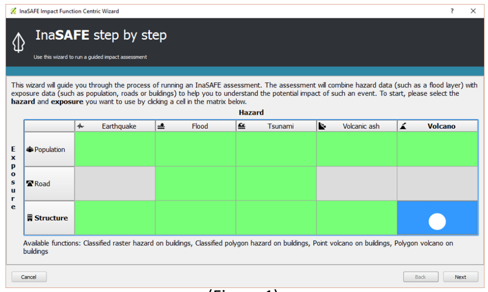
Roads: 79

Buildings: 5

Medical Centers: 0

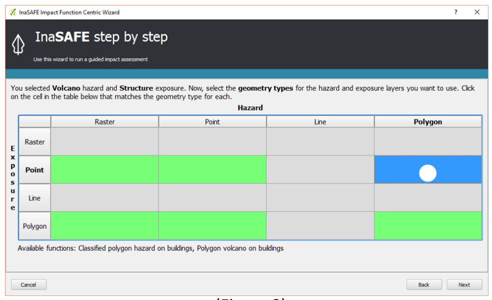
Summary Steps for Pyroclastic Flows on Effected Roads, Buildings, Educations Buildings , and Medical Centers in Latacunga

Step 1: Defined pyroclastic flow as the hazard layer, and indicated an analysis on structures and roads (Figure 1).

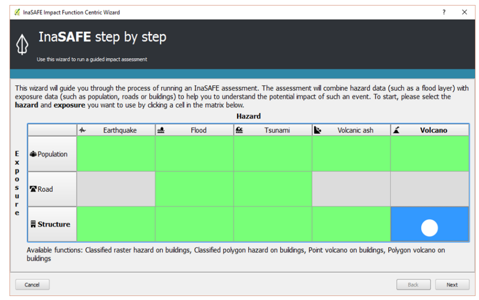


(Figure 1)

Step 2: Defined outcome of the result on the affected layers. The hazard layer of pyroclastic flow was a polygon. Roads and buildings were also defined as polygons (Figure 2). Education buildings and medical centers were points (Figure 3).

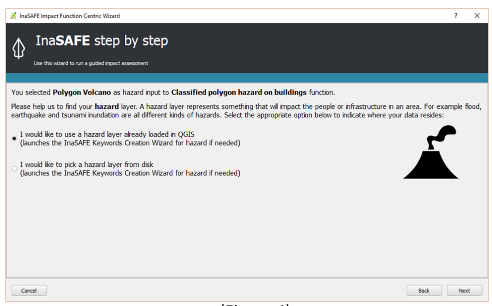


(Figure 2)



(Figure 3)

Step 3: The specific hazard layer was defined for the analysis as a pyroclastic flow polygon which was already loaded into QGIS (Figure 4).



(Figure 4)

(Results)

Results of the pyroclastic flow InaSafe report for roads, buildings, education buildings, and medical centers within danger are the following:

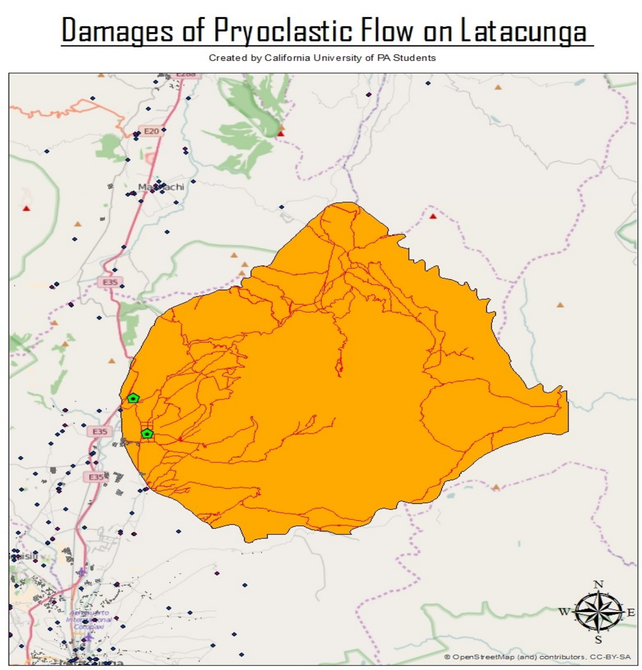
Education Buildings: 2

- GRAL LEONIDAS PLAZA GUTIERREZ
- AGLOMERADOS COTOPAXI

Roads: 213

Buildings: 1

Medical Centers: 0



General Actions for Latacunga and Surrounding Areas:

1. Encourage people in high risk areas to evacuate to permanent or temporary shelters.
2. Evaluate the affects of the disaster on public infrastructure such as roads, transportation lines, water supply, sewage, housing, hospitals, food supplies, and power supplies
3. Plan evacuation routes and maintain routes clear so that they remain usable.
4. Increase public preparedness through effective public communication and risk discussion. This is necessary for any effective public preparedness effort. Risk communication is defined as "communication intended to supply information to make informed decisions and discussions about risks to health, safety, and the environment (Paton, D. and Johnston, D., 2001).
5. Ensure that warnings are incorporated into the local emergency management planning. Make sure that warnings are effective and have a clear message that can reach all levels of the local population. Various methods of communication may have to be used (Paton, D. and Johnston, D., 2001).
6. Practice operational warning systems and evacuation methods.
7. Promote emergency planning kits such as water, extra food, and needed living supplies
8. Consider other important items, such as livestock or technology, and determine courses of action for how to move or care for said items. To be effective, this must be done before mudflows occur, but may be possible after a minor ash fall begins. Heavy ash fall, however, would halt such movements because of reduced visibility, difficulty in breathing, and the effects of ash on machinery.
9. During event, remain indoors as much as possible to reduce risk of exposure to ash. When going outdoors, use face masks to protect lungs from ash inhalation, as that may cause health problems. If face masks are not available, use moist cloths to reduce intake of ash.
10. Filter water to clean or maintain stored water if clean water is unavailable.
11. In case of extreme ash fall events, shovel ash off of roofs with weak structures to prevent damage or structural collapse.
12. Shake vegetation to reduce breakage of limbs or stems due to the weight of accumulated ash

During a volcanic eruption, a visual watch is extremely important. Eruptions do not necessarily occur at predictable times, rates, or intensities. Therefore there can be various signs that foresee how severe the eruption may be. Such signs can last for long periods of time before an eruption even occurs; so recording progression of volcanic activities is important. If an eruption results in mudflows, people must move as quickly as possible out of the high, moderate, and low risk zones to higher ground. If a mudflow develops, little time is available to move to safety. For example, during the 1877 eruption of Mt. Cotapaxi, mudflows originating at the summit of the volcano were reported to have reached Latacunga in only 30 minutes (.Paton, D. and Johnston, D., 2001). If heavy ash fall or cloudy weather obscures the volcano, the noise of a mudflow may at least provide some warning. This is why a warning system initiating from Latacunga would be helpful as it would allow for some time.

California University of Pennsylvania's Continuing Contribution to USAID and Disaster Relief in the Future

- Take hazard data about Mt. Cotopaxi and Latacunga and expand on them to create a comprehensive evacuation plan using different risk zones throughout the city and create other hazard guides.
- Attend workshops, conferences, and meetings with other schools to learn more about public awareness techniques for mapping and analysis.
- Grow the Youth Mappers Organization, and help the CalU GIS Club host map a thons for humanitarian needs.
- Incorporate humanitarian mapping into the Introduction to Geography course, and educate students on the importance of mapping unmapped areas around the world, especially vulnerable areas. This could be especially useful for the section focused on the Middle East and Africa.

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